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CAPITAL STRUCTURE DECISIONS: AN IMPLICIT CONTRACT OR A GOVERNANCE RELATION?

by
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1. *The Problem*

Two issues are important in both financial economics and financial management. (a) The determination of the financial structure of the firm which consists of (i) the capital structure (the debt equity ratio), and (ii) the ownership structure (the percentage of common stock held by the managers and the directors), and (b) the sharing of net returns (the dividend decision in particular) [1]. In general, these financial decisions of the firm depend upon (a) the nature of the financial requirements, (b) the cost of acquiring finances from different sources, and (c) the implications for the ownership and control rights.

There are two competing theories about the financial decisions of the firm. Jensen and Meckling (1976), who base their argument on information asymmetry [2], suggested that the relationship between the shareholders and the management would be an implicit contract. That is, the shareholders invest their money in the firm's capital assets and entrust to the management the utilization of these assets to generate profits. In general, the understanding would be that the management endeavors to maximize the total net gains and also resolve the distribution problem equitably. On the other hand, Williamson (1988, p. 576) argued that these financial decisions are

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[1] See, for instance, Jensen and Mekling (1976, p. 305), Jensen and Ruback (1983), and Harris and Raviv (1991, 1992).

[2] The Berle and Means (1932) position was that diffused shareholding would not provide the shareholders sufficient control even if they have the information and managerial skills. This would also result in consequences similar to the information asymmetry argument.

"better regarded as different governance structures (control mechanisms)". In particular, the market mode of organization (debt financing) will be replaced by internal organization (equity financing) depending upon the asset specificity and the associated business risk. As such it was pointed out that the shareholders retain control and decide various aspects which the management would be expected to implement. Two aspects of the governance argument are pertinent. (a) The shareholders have a right to govern the firm. For, as Fama (1990, p. S78) noted, contracts in organizations usually contain the provision that the rights regarding the decisions that affect the net cashflows are largely in the realm of the equityholders because they bear the risk associated with the net cashflows. (b) Williamson (1988, p. 580) argued that from time to time the shareholders are appraised of investment and strategic operating decisions before they are implemented and have a monitoring and control relationship with the management [3]. In the final analysis, the choice between these two organizational forms depends on the relative costs of conducting the business transactions [4].

The crucial dimension in both the approaches to the problem is the need for the organization to adapt itself to the nature, extent, and the frequency of the business risk [5]. See, for instance, Williamson (1983, p. 357). The implicit contracting approach takes the position that the shareholders devise monitoring and incentive mechanisms which (a) attempt to align managerial objectives with their own, (b) require the management to share risks to ensure bonding, and (c) delegate the strategic as well as the operational decisions to the management. In contrast, the governance argument implies that (a) the shareholders make all the decisions, (b) choose appropriate strategies and organizational arrangements which reduce the business risk [6], and (c) bear all the residual business risks.

As Harris and Raviv (1992, p. 67) pointed out there is practically no

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[3] To have a strong evidence of governance it is necessary to show that the shareholders initiate, not merely be appraised of, strategic decisions. The governance argument would be far more vulnerable in the context of operating decisions due to the frequency with which changes are necessitated.

[4] Most of the financial decisions are of a long term nature and have a wide ranging impact on many individuals. As such it would be difficult for the shareholders to enforce their decisions on the management on a continuing basis. It would be simpler to provide incentives to the management to align their objectives with those of the shareholders. A direct test of the difficulty of either of these propositions is, however, infeasible.

[5] TURNOVSKY (1970, p. 1064) and VICKERS (1987, pp. 162-3) characterize business risk as a situation in which the demand for the different products of the firm is uncertain.

[6] To be sure the management may also make these decisions in the implicit contracting framework.

empirical information on the relevance of one of these organizational arrangements over the other [7]. The present study, based on a cross-section of firms in the chemical and engineering industries in India [8], is an attempt to set up an analytical structure and statistically examine the relative strength of these competing hypotheses.

2. *The Framework*

Consider a market environment in which there is a high degree of business risk. In such a case there would be a necessity for frequent adjustments in the deployment of assets, marketing strategies and so on. In the context of a contractual arrangement [9], the management would be expected to choose an appropriate product strategy and organizational structure to fit the external environment [10]. They would also be responsible for the capital structure and dividend decision. However, if the external control by the shareholders is weak, due to the separation of ownership from control alluded to by Berle and Means (1932), risk averse managers may shy away from such changes so long as their own interests are not in jeopardy [11]. It would then be necessary for shareholders to identify and implement suitable incentive arrangements which encourage the management to choose effort levels and attitudes towards risk in line with their objectives. See, for instance, Watts and Zimmerman (1983) and Thompson (1988, p. 65).

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[7] Utilizing a methodology in which the comparison is not explicitly set up SMITH and WATTS (1992, p. 281) concluded that "contracting theories are more important in explaining cross-sectional variation in observed financial, compensation, and dividend policies". To the extent we are aware of it the governance argument has not been tested empirically so far.

[8] Empirical evidence can be either information collected from the corporate board rooms or indirect evidence based on statistical analysis. As of now the first approach appears to be infeasible since a direct question will not yield a satisfactory answer.

[9] Note that the information asymmetry (with respect to the production process in particular) which the shareholders experience gives rise to contractual delegation. The shareholders experience some control loss.

[10] See, for instance, EASTERBROOK (1984, p. 653), BOLTON and SCHRAFSTEIN (1990), BRANDER and LEWIS (1986), and BRANDER and SPENCER (1989).

[11] See, for example, GRABOWSKI and MUELLER (1972, p. 9), HERENDEEN (1975, p. 95), JENSEN and RUBACK (1983, pp. 29-30), EASTERBROOK (1984, p. 653), and AGARWAL and MANDLEKAR (1987, p. 824).

Alternatively, JOHN (1987, p. 624) and JENSEN and MURPHY (1990, pp. 242 ff) argued that if the capital markets are perfect, the shareholders can anticipate managerial motivations and intentions and offer share prices accordingly. Capital market imperfection is one of the reasons for the nonalignment of the objectives of the shareholders and the management.

Managerial remuneration (a fixed cost) and market based payment schemes like the stock options (risk sharing) are prominent [12]. In particular, the common stock owned by the managers and the directors is an incentive for them to operate in such a way as to maximize the value of common stock (which is in the interest of the shareholders) [13].

However, as Smith and Watts (1992, p. 275) argued, the shareholders would consider reneging to be possible whatever may be the salary and compensation schemes offered to the management. For, it is difficult for them or outside board members, who do not have the specific knowledge of the profit prospects of the firm the same way the management does, to observe all the investment alternatives from which the manager chooses. This generates a necessity on the part of the management to utilize certain measures which can assure the shareholders of their bonding (alignment of objectives).

Grossman and Hart (1982, p. 109) noted that by issuing debt the "management deliberately changes its incentives in such a way as to bring them into line with those of the shareholders because of the effect on market value. In other words, the management bonds itself to act in the shareholder's interest". That is, the debt equity ratio chosen by the management can be looked upon as a bonding device [14]. Clearly, their choice of the debt equity ratio depends upon the extent to which (a) strategic and organizational changes can absorb the business risk, and (b) the incentive schemes succeed in aligning the objectives of the two parties in the contract.

Turnovsky (1970, p. 1064) also noted that an increase in the debt equity ratio, to the extent it raises the fixed cost of project financing, results in a financial risk. When the business risk is high and the returns from investments are uncertain the management cannot assure the shareholders that the anticipated profits and capital gains will be realized at the expected time. Hence, while undertaking additional investments the management may prefer to payoff higher dividends to indicate bonding [15]. Easterbrook

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[12] See Flath and Knoeber (1985, pp. 93 ff), Agarwal and Mandlekar (1987, pp. 823 ff), Jensen and Murphy (1990, p. 226), and Smith and Watts (1992, p. 264).

[13] This aspect has been considered extensively in Jacquemin and De Jong (1977, p. 161), Chang and Choi (1988, p. 150), Fama (1990, p. S73), and Glazer and Israel (1990).

[14] Also see Kort (1990), Harris and Raviv (1991, p. 306 ff), and Smith and Watts (1992, p. 275).

[15] The classic argument of Lintner (1956) is that dividend decisions are primary from the viewpoint of the shareholders. Many studies, including those of Rao and Sharma (1984) and Balasubramanian (1993) for the Indian context, found this to be empirically valid. In such a case, dividend decisions will be exclusively under the control of the shareholders rather than the management.

(1984, pp. 654 ff) also pointed out that by paying dividends the management increases the need to go to the stock market to raise funds thus allowing shareholders to evaluate their performance.

In sum, it should be noted that in the implicit contracting argument the shareholders (a) calibrate the external environment, (b) choose incentives provided to the management [16], and (c) delegate the strategic, capital structure, and dividend decisions to the management. The management, in its turn, (a) makes an attempt to absorb environmental uncertainty by making appropriate strategic and organizational choices, and (b) convince the shareholder of the need to share the residual business risks with them by choosing appropriate bonding devices [17].

By way of contrast, note that the governance argument proceeds as follows. The shareholders (a) observe the market environment, (b) examine the extent to which strategic and organizational change can absorb the business risk, and (c) decide the incentive mechanisms that would be necessary to make the management implement their choices. However, as with the contractual mode, these mechanisms can mitigate the business risk only partially. Hence, the financial choices of the shareholders will have to be designed to account for the residual business risk.

Risk averse shareholders may want to increase debt as the residual business risk increases [18]. For, if the risky projects in which they invest do not yield the expected returns the bondholders also share the risks whereas the fixed cost of debt alone needs to be borne if they are successful. Such an argument was advanced by Harris and Raviv (1992, p. 60). Secondly, given the degree of business risk, the shareholders of highly growth oriented firms are likely to increase the debt equity ratio and accept the implied financial risk.

Dividend claims of the shareholders depend on a number of factors. When the business risk is high but the long run prospects of the firm are good risk averse shareholders may consider it prudent to stabilize the base of the reserves and surpluses on which further borrowing and continuity of the firm depends. Consequently, they will reduce their dividend claims [19].

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[16] This choice depends entirely on their assessment of the environment and it will be announced before the management makes any strategic or organizational changes.

[17] The purpose of the management is not to gain control unlike the Berle and Means (1932) argument.

[18] There can be business risk induced by asset specificity in addition to that implied by the external market conditions. As Williamson (1988) argued, the shareholders (or the management as the case may be) would then tend to reduce the debt equity ratio.

[19] This argument is due to Herendeen (1975, p. 95).

However, they may take out higher dividends whenever they feel that they will lose substantially if the expected profits and capital gains are not realized [20]. In a similar fashion, as DeAlessi and Fishe (1987, p. 41) remarked, the shareholders may insist on regular dividend payments to reduce the need to monitor managerial decisions. For, the retention of earnings gives the managers an opportunity to divert resources to their advantage even if they continue to make investments which increase the market value of the firm.

The fundamental differences between the two approaches can be summarized as follows:

(a) In the implicit contracting approach incentives like wage payments and the shareholding by the managers and their relatives determine the manager's response to the choice of the capital structure and the dividend decision. The management does not have any role in the governance framework.

(b) In a governance relation it should be expected that strategic and organizational changes which the shareholders want to introduce would have an important role in determining the incentives offered to the management. On the other hand, in an implicit contract even the strategic and organizational decisions are likely to be initiated by the management and the wage and incentive fixation would not take into account anything beyond the loosely defined growth objective and guidelines for their changes based on the business risks so as to achieve some sharing of risks and consequent alignment of objectives.

(c) Risk sharing with the bondholders or risk aversion with specific assets is the motivation for debt financing in the governance framework. On the other hand, the implicit contracting framework visualized it as a device to bond the managers with the shareholders.

(d) The direction of change in dividends induced by business risk in both the approaches is the same. The only difference is the bonding property in the context of the implicit contract [21].

3. *The Empirical Specification*

The present study is based on the data for a cross-section of firms in

[20] See, for instance, Grabowski and Mueller (1972, p. 10) and Kort (1990, p. 377).

[21] The argument of the present section can only explain the operational differences between the implicit contract and governance frameworks if and when one or the other is adopted. The basic reasons for the choice will have to be found elsewhere.

the chemical and engineering industries in India as tabulated in Saha (1993). The basic sources of data are the balance sheets, the profit and loss accounts, and the statements of the chairmen of these companies as published in the various issues of the Bombay Stock Exchange directory. All the firms for which complete data regarding organizational structure and control could be assembled were taken into account. The data is for 46 firms in chemicals and 25 firms in the general engineering industry. The data pertain to the years 1986-92 in most cases. As Steer and Cable (1987, p. 20) argued, this length of time is "sufficiently long for short run influences to be (minimized)..., but sufficiently short so that most firms would have a stable organizational form over most of the period". This section provides a detailed description of the classification of the variables and the maintained hypotheses.

The capital structure decision is represented by the debt equity ratio (*DEBT*). Following Turnovsky (1970, p. 1065) it was defined in terms of book values rather than market values. Similary, dividends per share (*DIND*) was utilized as a measure of the sharing of gains.

The explanatory variables were classified in the following manner: (a) market environment, (b) strategy variables, and (c) incentive and monitoring measures. Consider each of them sequentially. Business risk is the major variable representing the market environment. It was defined by the coefficient of variation of sales (*CVSI*) = standard deviation of sales/mean net sales (expressed as a percentage) [22]. It can be generally expected that both the management and the shareholders would be risk averse when subjected to a high business risk. In such a case they would prefer to increase equity financing to spread the risk among a large number of shareholders. The debt equity ratio is expected to decrease as *CVSI* increases. However, if the capital structure decision is a governance relationship there is a possibility that under unfavorable market conditions the shareholders would have an advantage in sharing the risks with the bondholders while the gains accrue to them if the market environment is good. That is, the debt equity ratio will increase with *CVSI*. Similarly, in the context of an implicit contract the management may feel that frequent changes in operational decisions would be necessary to accommodate the business risk and that this may necessitate convincing the shareholders by providing a bonding signal. The bonding effect would dominate risk aversion of managers when the firms are highly

[22] It would be equally plausible to argue that when capital markets are perfect the share price changes would accurately reflect the business risks. However, the share prices are not a good indicator when the capital markets are imperfect. Hence, *CVSI* was preferred.

diversified and the capital assets are not very specific (as in the context of the chemical industry). The debt equity ratio is expected to increase with *CVSI* in such a case. It would be generally expected that the desire to build the reserve base when subjected to business risk would reduce dividend payments irrespective of who the decision makers are. Similarly, when confronted with a high business risk the shareholders may reduce the wages and salaries component (a fixed cost) and offer equity participation to the management to share risks and align objectives more closely.

Short term liquidity problems for financing working capital have been well documented in the context of the Indian corporate sector. See, for example, Dixit (1992). It can be expected that the working capital shortage reduces the production potential and makes it difficult to convert fixed assets to profits. Under these conditions the decision makers in both forms of the organizational arrangements may feel that committing to more fixed costs by way of a high debt equity ratio would not be desirable. In general, the shareholders may refrain from offering greater incentives to management for the same reason. However, when the asset specificity and fixed costs are high the shareholders may prefer to provide an incentive to the management so as to reduce the tendencies towards such a risk averse behavior. Fazzari and Petersen (1993, p. 330) argued that such changes in the capital structure decision can be observed when the firm confronts short term liquidity problems.

A perusal of the data indicated that several firms in the sample were private limited companies until a few years ago. Such young quoted companies tend to have a high debt equity ratio, report more accounting profits, and offer a lower dividend per share in order to build an adequate base to finance investments, and expect to attract management due to their growth prospects rather than the incentives they offer. Some of these aspects were considered by Grabowski and Mueller (1972) earlier. To capture these effects a dummy variable (*DUMY*) was defined as

$$DUMY = \begin{cases} 1 & \text{if the firm was a public limited company for at least 8 years} \\ 0 & \text{otherwise} \end{cases}$$

One of the variables which prominently exhibits the future prospects of the firm is the rate of growth of capital assets. Both the shareholders and the management may consider an increase in the growth rates favorably [23]. The management may favor it because it would generate new career opportunities and better salaries for themselves. On the other hand, the sharehold-

[23] See, for instance, MARRIS (1971) and WILLIAMSON (1971, p. 380).

ers may find enhanced profits and value increasing possibilities as the size of assets increases [24]. Hence, the average rate of growth (*GRTH*) of the total net assets of the firm over the five years under consideration was included. In general, *GRTH* will be expected to have a positive effect on all the variables of the study except wages and salaries paid to the managers. For, the growth prospects of the firm may be sufficient to attract management even if the other incentives are not provided by the shareholders.

When confronted with persistent business risk the firm's decision makers would make an attempt to change the business strategy and organizational structure though it may be very expensive to make frequent changes in the short run. In general, following Caves (1980, p. 64) and Chandler (1992, p. 82) it can be maintained that strategies of the firm will be determined by the manager's perception of the market potential and the firm's distinctive competencies. However, following Whittington (1988, p. 256) and Lyles and Schwenk (1992, pp. 157-8), it can be argued that it is not easy to define the market environment the way it is. For, it can be realized only through the perception of the shareholders and/or the management which has been built up over time in the form of distinctive competencies. This has led Caves (1980, p. 74) to remark that there has been no satisfactory explanation of the causation between environmental factors and corporate strategy. Hence, following Chandler (1982, p. 86) it would be more practical to represent strategy as exogenously determined. The product choice and marketing strategy have been identified as the basic strategic alternatives. In particular,

PRST (product strategy based on the technological dependence of the the product range):
- 1 if the products were mostly interdependent
- 2 if the products were somewhat related
- 3 if distinct groups were identifiable

DMND (market relationships among products):
- 1 if they are mostly related
- 2 if somewhat related
- 3 if distinct groups were identifiable

The major organizational response to business risk in most of the firms is the product diversification introduced through divisionalization. To capture this effect a variable (*DIVR*) was defined as

[24] This proposition was stated negatively by MILGROM and ROBERTS (1992, p. 497).

DIVR (the organizational arrangements for new product introduction):
1 if no new product divisions were introduced or the new divisions were not product divisions (they may be functional divisions instead)
2 if new product divisions were a result of acquisition or collaboration with other firms
3 if new products were introduced through separate product divisions

In general, all these variables can be expected to have a negative effect on all the other variables considered in this study. For, capital structure changes would not be necessary if organizational changes can accommodate business risk.

One of the natural choices of incentives is the wage payments to the workers and the management. This was defined by

WAGE: wage payments to the total cost of goods sold (expressed as a a percentage)

In general, this variable was expected to appear with a negative sign in the *DEBT* and *DIND* equations if the implicit contracting hypothesis is valid. For, a higher incentive to the management reduces the need for bonding. Jacquemin and DeJong (1977, p. 163), Chang and Choi (1988, p. 150) and others noted that the behavior of the management is different when the shareholding by the managers and the directors exceeds a threshold like ten percent. Hence,

EQTY: the percentage shareholding of the managers and their relatives

was included as the other variable belonging to the classification of incentives.

The specification of the two models can now be summarized as follows:

Implicit Contract:
DEBT and *DIND* = *f*(*CVSI, LQID, DUMY, PRST, DMND, DIVR, WAGE, EQTY*)
WAGE and *EQTY* = *f*(*CVSI, LQID, DUMY*)
Governance Relation:
DEBT and *DIND* = *f*(*CVSI, LQID, DUMY, PRST, DMND, DIVR*)
WAGE and *EQTY* = *f*(*CVSI, LQID, DUMY, PRST, DMND, DIVR*)

In particular, in the implicit contract framework, (a) the *WAGE* and *EQTY* variables appear in the financial decisions, but (b) the strategy and organizational structure variables will not determine the choices of *WAGE* and *EQTY*. On the other hand, if the capital structure decision is a governance relationship (a) the *WAGE* and *EQTY* variables cannot appear in the *DEBT* and *DIND* equations, whereas (b) the strategy and organizational structure will modify the choice of incentives. A comprehensive test of the organizational choice implicit in the capital structure decision is therefore possible.

4. *The Results*

Each of the equations of the models implied by the two organizational alternatives were computed by a stepwise regression procedure [25]. Variables were added in the decreasing order of their contribution to $\bar{R}^2$. However, the equations were corrected for heteroscedasticity by utilizing the White (1980) procedure.

For the chemical industry the *DEBT* and *DIND* equations were

$$\begin{aligned} DEBT = \; & \underset{(17.53)}{2.72} + \underset{(13.02)}{1.43}\, GRTH - \underset{(7.62)}{0.044}\, WAGE - \underset{(5.04)}{0.31}\, LQID \\ & - \underset{(6.64)}{0.49}\, DUMY - \underset{(7.75)}{0.018}\, EQTY + \underset{(2.89)}{0.0084}\, CVSI \qquad \bar{R}^2 = 0.99 \end{aligned}$$

where the numbers in the brackets are the *t*-values of the corresponding coefficients.

$$\begin{aligned} DIND = \; & \underset{(14.41)}{18.53} + \underset{(13.16)}{5.49}\, DUMY - \underset{(2.89)}{1.82}\, DIVR + \underset{(4.13)}{2.78}\, GRTH \\ & - \underset{(6.03)}{0.12}\, EQTY \qquad \bar{R}^2 = 0.99 \end{aligned}$$

Similarly, the two equations explaining the choices of the incentives were

$$WAGE = \underset{(16.54)}{8.35} + \underset{(17.97)}{6.30}\, DUMY - \underset{(12.60)}{0.09}\, CVSI \qquad \bar{R}^2 = 0.99$$

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[25] The model representing the implicit contractual relation is recursive while that implied by the governance relation is a reduced form specification. (Since these are simultaneous decisions of the shareholders estimation by the seemingly uncorrelated regression procedure can also be justified). Hence, ordinary least squares estimators are adequate in both the cases.

$$EQTY = \underset{(12.01)}{8.57} - \underset{(4.34)}{1.38}\ LQID \qquad \bar{R}^2 = 0.86$$

The following observations are pertinent: (1) the equations representing the incentives contain only the environmental variables. In particular, (a) the positive sign of *DUMY* in the *WAGE* equation indicates that relatively new firms pay lower wages to management who are attracted to them primarily due to the growth prospects, (b) an increase in business risk has a negative effect on *WAGE* due to its fixed cost nature (the shareholders prefer that the management share risks with them), and (c) the liquidity constraint generally makes the shareholders risk averse and they refrain from committing the management to greater shareholding. Further, these equations do not contain any strategy variables. (2) Consider the *DEBT* and *DIND* equations. They contain environmental, strategic, as well as incentive variables. In particular, the following inferences are possible. (a) Business risks are accommodated by a diversified product strategy implemented through a divisionalized organizational set up. This reduces the need for making changes in the capital structure *per se*. This is indicated by the negative sign of *DIVR* in the *DIND* equation. (b) Business risk makes the management choose a higher debt equity ratio. This indicates a greater need for bonding with the shareholders since the entire business risk cannot be accommodated by the changes in strategy and organizational structure. (c) The management is generally risk averse to short term liquidity problems. The inability to increase production and generate profits from the fixed assets inhibits them from committing to greater fixed costs implicit in a higher debt equity ratio. (d) An increase in capital formation is generally financed by *DEBT* and higher dividend payments are used as a bonding device. (e) New firms have a higher debt equity ratio and pay lower dividends so as to enable them to build the reserve base to support the increased borrowings. (f) Incentives provided to the management by way of *WAGE* and *EQTY* assure an adequate alignment of the objectives of the shareholders and management and reduce the need for the management to resort to *DEBT* and *DIND* as further bonding devices [26].

[26] An alternative *DIND* equation was equally good from an econometric point of view.

$$DIND = \underset{(19.61)}{20.97} + \underset{(12.23)}{5.01}\ DUMY - \underset{(6.56)}{2.51}\ DIVR + \underset{(8.32)}{4.44}\ GRTH - \underset{(8.42)}{0.094}\ CVSI \qquad \bar{R}^2 = 0.99$$

Neither *WAGE* nor *EQTY* appear in this equation. It is possible that the dividend decisions are primary from the shareholder viewpoint in the sense of LINTNER (1956). If this argument is

These results support the inference that in the case of chemical industry the capital structure decisions are basically an implicit contract. For, (a) the *WAGE* and *EQTY* equations indicate that the strategic decisions have no effect on them (since the later choices are left to the management), and (b) an appropriate choice of incentives reduces the need to construe the financial decisions as bonding devices.

Consider the case of the general engineering industry. The best available results were the following:

$$\underset{}{DEBT} = \underset{(16.49)}{8.67} - \underset{(7.38)}{0.91}\ PRST - \underset{(5.16)}{0.048}\ CVSI - \underset{(5.58)}{2.15}\ LQID \qquad \bar{R}^2 = 0.99$$

$$DIND = \underset{(3.26)}{7.71} + \underset{(3.62)}{7.53}\ DUMY + \underset{(4.16)}{5.45}\ GRTH \qquad \bar{R}^2 = 0.99$$

$$WAGE = \underset{(27.87)}{21.60} - \underset{(10.89)}{7.22}\ GRTH \qquad \bar{R}^2 = 0.99$$

$$EQTY = \underset{(4.12)}{13.98} - \underset{(4.09)}{5.58}\ PRST + \underset{(3.97)}{9.40}\ GRTH \qquad \bar{R}^2 = 0.68$$

It should be noted that the determination of incentives is affected by the product diversification strategy of the firms and the incentive variables do not appear in the *DEBT* and *DIND* equations. The only possible conclusion is that the capital structure decision is a governance relationship.

The following additional evidence is noteworthy: (a) *CVSI* appears with a negative sign in the *DEBT* equation. Risk averse attitude of the shareholders is evident. Further, it is not possible to interpret this as a bonding device utilized by the management. (b) *PRST* and *LQID* have the expected signs in the *CVSI* equation. (c) The *DIND* equation suggests that new companies, which place emphasis on taking advantage of growth prospects tend to base the dividend payments on *GRTH*. In other words, the shareholders are generally risk averse and prefer to take out dividends as early as possible and utilize the stock market to obtain the additional financing for new investments. (d) The *WAGE* and *EQTY* equations indicate that the shareholders prefer the management to share the risks of growing investments with them rather than offer higher wages which force them into fixed costs. However, the need to have the management sharing the risks is

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accepted, it should be concluded that in an implicit contractual arrangement the management has the authority to make only the capital structure decision.

reduced if the product strategy can accommodate the business risk. Hence, *PRST* appears with a negative sign in the *EQTY* equation [27].

What can be the reason for the asymmetric result in these two industries? One possibility, on the basis of the available data, is the following. In the case of the general engineering industry the shareholding by the managers and their relatives is close to the threshold value identified by Jacquemin and DeJong (1977, p. 161). The average value of *EQTY* over the sample is 10.34 percent as against 7.19 percent for the chemical industry. Further, whereas 40.0 percent of the firms in the general engineering industry have a value of *EQTY* higher than 10 percent, the chemical industry only has 23.9 percent of the firms statisfying this property. In general, it is to be expected that the management gains control whenever the value of *EQTY* is above the 10 percent threshold [28]. In such a case, the shareholders cannot leave the decision making in the hands of the management. The implicit contract becomes inefficient and the shareholders must reassert their control through the governance structure [29].

5. *Further Observations*

The above explanation of the difference between the capital structure decisions should be considered tentative at best. For, it is based on the logic of Berle and Means (1932) that the management usurps control when there is a significant difference between ownership and management thus

[27] One puzzle could not be resolved. The evidence indicates that the shareholders want the management to share the risks with them. Hence, they offer a higher percentage of shares to the management and their relatives. In doing so they know that they lose control and must resort to a governance structure. They will probably do this if the costs of the implicit contractual alternatives are far greater. It is not possible to offer any empirical evidence for this argument. In general, there is very little practical content in the attempts to specify the costs of different organizational forms.

[28] Jensen and Warner (1988) and Leech and Leahy (1991) pointed out that a potential controlling coalition of shareholders may emerge when the management has such shareholding. One way of interpreting this is to say that the shareholders will regain control. However, the alternative interpretation that the implicit contract will remain efficient under the threat of the controlling coalition is equally plausible.

[29] A second possibility can also be suggested. Suppose the capital assets of the firm are very specific to it. If the business risk is sought to be neutralized by extensive diversification utilizing a divisionalized structure the shareholders and the board of directors may find the control loss to be significant. In such a case, they may try to improve control through a governance structure. However, asset specificity is not essential to this argument. It is therefore difficult to examine the asset specificity argument of Williamson (1988) empirically.

rendering the implicit contract ineffective. However, there is as yet no definitive evidence that the management gains control whenever *DEBT* or *EQTY* values are high. Any conclusive evidence on managerial preferences can be obtained only from time series analysis of different firms [30]. Rao (1994) has recently developed a direct test of the hypothesis. Empirical work along these lines is in progress and will be reported elsewhere.

Capital market imperfection cannot, by itself, be a sufficient explanation for the share prices becoming an inefficient signal to shareholders. There is a possibility that shareholders take into account a more general measure like the market value of common stock. Restructuring the decision models in a more encompassing framework may strengthen the results of the present study. Experiences with these extensions will be reported elsewhere.

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[30] We observed that subsample behavior (when separated on the basis of the threshold value of *EQTY*) was broadly consistent with the above results. Hence, there can be differences in behavior across different firms which a cross-section sample cannot capture.

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DECISIONI SULLA STRUTTURA DEL CAPITALE: CONTRATTO IMPLICITO O MECCANISMO DI CONTROLLO?

Questo articolo formula un modello per discriminare tra il contratto implicito e una caratterizzazione della struttura di controllo relativamente alle decisioni sulla struttura del capitale. Utilizzando dati cross-section per le industrie chimiche e di ingegneria si mostra che le imprese chimiche sono caratterizzate dal contratto implicito mentre quelle di ingegneria mostrano una caratterizzazione di controllo.

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TESTING DIFFERENT THEORIES: AN EXPERIMENTAL APPROACH TO BARGAINING GAMES

by
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1. *Introduction*

A great deal of published papers aims at describing whether people's behaviour is *rational* or not; the idea of rationality economists have in mind coincides with the equilibrium solutions proposed in theoretical models. For instance, in game theoretic models a behaviour is rational when it maximizes the agent's payoff.

On the contrary, the profession is becoming more and more aware, as a result of the poor performance of the above theoretic models in experimental investigations, that *either* people do not behave in a rational way *or* the idea of rationality they follow in their decisions is different from the economists' one [1].

The above arguments highlight the main purpose of this paper: to test experimentally a standard non-cooperative game presented in the literature, comparing the performances of the "game theoretic" solution based on the maximisation of the agents' monetary pay offs, and of a different solution, where the idea of rationality is extended to cover also possible non monetary (psychological) determinants of people's behaviour.

The paper is organised as follow: Section 2 outlines the standard

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[1] An argument against rationality is that people follow *rules of thumb*; however even this behavior can be interpreted as rational if we assume that rules of thumb are adopted in order to minimize transaction costs involved in decisions.

bargaining models, building on two very well known theories, Section 3 sketches the main results of the previous experiments on bargaining, Section 4 presents a *minimum acceptance level* model, which might explain a different *rational* behavior, Section 5 displays the experimental settings while Section 6 reports the data analysis. Section 7 highlights the main results of the paper, while the experiment's instructions and full results are reported in the Appendices at the end.

2. *The Model*

Bargaining theory has received a lot of improvements recently. There is a debate in the literature between the approach of Selten (1978), Roth et al. (1981), which identifies *fairness* as a crucial element in bargaining between individuals, and the game theoretic approach revitalized by Rubinstein (1982), Binmore (1982), Shaked and Sutton (1984), where the process of offers and counteroffers is modelled as a formal non-cooperative game, and where the theory identifies the agreements that can be sustained as equilibria of the game.

The economic environment of both the approaches is the same: two people have to bargain about some amount of money, and there exists an advantage for one of the two parties (usually only one part can make the last offer); the sequence of offers and counteroffers goes ahead for a finite period of time, until an agreement is reached or until time runs out. When the bargaining does not end up in the first period and instead involves t periods, people have to discount the amount of money they will receive at the end of the sequence: it is therefore like a *shrinking pie*. If the agreement is not reached, the bargaining ends, and there are negative economic consequences for both players [2].

The difference between the two approaches is therefore in the determinant of the behaviour and, consequently, in the final agreement reached in the equilibrium: for the *fairness* approach, the solution tends to share *equally* the amount of money; for the game theoretic approach the solution yields a sharing of the money where the player with the strategic advantage gets almost everything, and very little is left to the other player. The two theories have different arguments in the individual utility function.

In the game theoretic approach the model is as follow: the pie is an

[2] Negative economic consequences because both players end up the bargaining with nothing.

amount of money Θ, there are n players and player i has a utility function

$$U^i = U^i(\Theta) \qquad \text{with } i = 1, 2, ..., n \qquad (1)$$

Players' utility functions are increasing in $x_i\,\Theta$ (with $i = 1, 2$), where $0 \leq x_i \leq 1$ is the share of the pie they get. At every time t (odd), player 1 makes an offer $(1 - x_1)\,\Theta$ to player 2, where $0 \leq x_1 \leq 1$ and $x_1\,\Theta$ is the amount of money player 1 wants to keep of the hole pie. Player 2 can either accept or refuse the offer; if he accepts the game is finished with an agreement. If he rejects, at period $t + 1$ he makes a counteroffer $x_2\,\Theta$ to player 1, where $0 \leq x_2 \leq 1$ and $(1 - x_2)\,\Theta$ is the amount of the pie player 2 wants to keep for himself. From one period to another players discount the monetary value of the pie at the rate δ, with $0 < \delta \leq 1$. If the agreement is not reached at time $t + 1$, the sequence of offers and counteroffers goes ahead; however it can last at the most for T periods.

The solution in the game theoretic approach is reached at the first period, working it out by *backward induction*; hence the subjects/players reach immediately the agreement and the *subgame perfect equilibrium* initial (first) offer is

$$(1 - x_1)\,\Theta = (\delta - \delta^2 + \delta^3 - \delta^4 + ... - \delta^{T-1})\,\Theta \text{ (if } T \text{ is odd)} \quad (2)$$

$$(... + \delta^{T-1}) \qquad \text{(if } T \text{ is even)}\,[4].$$

In the *fairness* approach the pie is still Θ but the individual utility function involves both monetary and non-monetary elements: the latter are given by the degree of *fairness*, i.e. the higher the player's *fairness* the greater the utility function. Even with this approach the solution is reached at the first period: the player receiving the first offer recognises that a 50/50 offer is the best combination between money and *fairness*.

[3] This is a monetary utility function. If a subject has a monetary utility function, her/his utility *only* depends upon the amount of money the subject gets during the bargaining. No other bargaining element is involved in the domain of the utility function, as for instance the relative percentage of the pie received by the subject at the end of the bargain. Hence a monetary utility function predicts that a subject will accept an amount ε very close to 0, given that ε is better than nothing.

[4] If T is odd, player 1 knows, by backward induction, that at period T he/she will get all the pie, because any offer $\varepsilon > 0$ but very close to 0 will be accepted by player 2 (ε is better than nothing if the utility function is (1)). Therefore at $T - 1$, player 2 makes an offer such that player 1 is just indifferent between accepting and refusing: this offer is $x_2 = \delta\,\Theta$, i.e. $(1 - x_2) = (1 - \delta)\,\Theta$. At period $T - 2$, player 1 will use the same procedure, and will make an offer $(1 - x_1) = \delta(1 - \delta)\,\Theta$, i.e. $x_1 = (1 - \delta + \delta^2)\,\Theta$, and so on.

3. *Earlier Studies on Non-cooperative Bargaining* [5]

Following the debate on bargaining, a lot of attention has recently been paid to experiments aimed at testing the above approaches. The problem is that the majority of these displayed the poor performance of both the above approaches, when tested with people's behaviour in laboratory.

Güth, Schmittberger and Schwartz (1982) made an experiment with one period bargaining games (i.e. $T=1$), which are called *ultimatum* games [6], involving both "naive" subjects (inexperienced subjects) and "experienced" subjects [7]. Their results do not give support to the game-theoretic approach, while the average opening offer was around 65 percent of the pie. They observed that the strategic advantage could not be exploited because subjects were ready to punish the rivals if they asked "too much". But also the *fairness* approach did not work very well, as long as they noticed an average opening offer of 69 percent of the pie for "experienced" subjects. Therefore the agreements are usually closer to the 50/50 solution than the game theoretic one, but the evidence that people want really to be *fair* is not so strong.

Binmore, Shaked and Sutton (1985) criticised the results obtained by Güth et al. (1982) arguing that the one-period ultimatum game is a special case, and made an experiment with a 2-period bargaining game. In this case the authors found a bias toward the equilibrium predictions of the game theoretic approach; the reason for this difference with the previous experiment is due to the negligible cost of an "irrational" response to an optimal opening offer (i.e. player 2 does not lose too much given that when $T = 1$ his expected game theory payoff is ε) with one-period game; with 2-period games this cost becomes higher and it is therefore more expensive to play with irrationality.

Güth and Tietz (1987) tested the same 2-period ultimatum game of Binmore et al., but with different discount rates. They rejected Binmore, Shaked and Sutton's results, because subjects' behaviour was clearly against the game theoretic solution, arguing that Rubinstein's approach has no predictive power.

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[5] There also exists a literature on *cooperative* bargaining, which is not part of this research; a good review of the existing experiments in this field is in SOPHER (1993).

[6] A bargaining game with only one period is called *ultimatum* game because the player in charge of the first (and unique) offer can make the following ultimatum: "either you accept this offer or you end up with nothing". In this paper we define as ultimatum game any *final* subgame of the whole bargaining game.

[7] "Naive" subjects are students that play the game for the first time; "experienced" subjects are the same students that play the game one week later. With ultimatum games, the subgame perfect equilibrium predicts that player 1 takes all the pie.

Another paper in response to Binmore, Shaked and Sutton's results was written by Neelin, Sonnenschein and Spiegel (1988). Their experiment highlights for the first time that neither the game-theoretic approach nor the *fairness* approach predicts the bargaining behaviour observed on different subjects. They made people play bargaining games with 2 periods, 3 periods and 5 periods. Their conclusion is important because it points out the poor predictive power of both the above approaches, and introduces the possibility that people's bargaining behaviour may be better explained by a utility function different from (1), where also psychological elements are taken into account.

This possibility is deepened by the work of Ochs and Roth (1989), who made a complex experiment on 2-period and 3-period bargaining games, with subjects having equal and different discount rates [8].

Following the new insight introduced by Neelin et al., they tested the predictive power of both the above approaches, either under the assumption that bargainers' utility is measured by their monetary pay offs, or that it is measured by non-monetary payoffs. The best results they got are related with a utility function which is defined over non-monetary and monetary elements. The non-monetary elements are expressed by some threshold monetary levels, which identify the separation line for a subject with the strategic disadvantage between an offer that can be accepted and an offer that *must* be rejected because it is "too low". In this case, the positive utility of getting an amount of money is lower than the (psychological) disutility of accepting a low offer. In their study, this assumption could explain, for instance, the pattern of rejected offers and irrational counterproposals (because they leave the subject with less money than what he could have accepted).

Ochs and Roth have given the major impulse to this paper: in Section 4 we try to give a formal description of a utility function which involves threshold monetary levels; the experiment we are going to present in Section 5 will show once again the poor performance of the previous theories and will instead highlight the good predictive power of a minimum acceptance level model in explaining average people's behavior, in a context where the monetary elements are even stronger than those usually included in a standard *ultimatum* game.

[8] To use different discount rates for each subject dealing with a bargaining game, they divided the pie in chips. Clearly, for different people these chips were worth different amounts of money, i.e. subjects with a low discount rate had a value of a single chip lower than those with a high discount rate, for every period of the bargaining, except the first one.

4. *Relevance of Non-monetary Elements: A Minimum Acceptance Threshold Model of Bargaining*

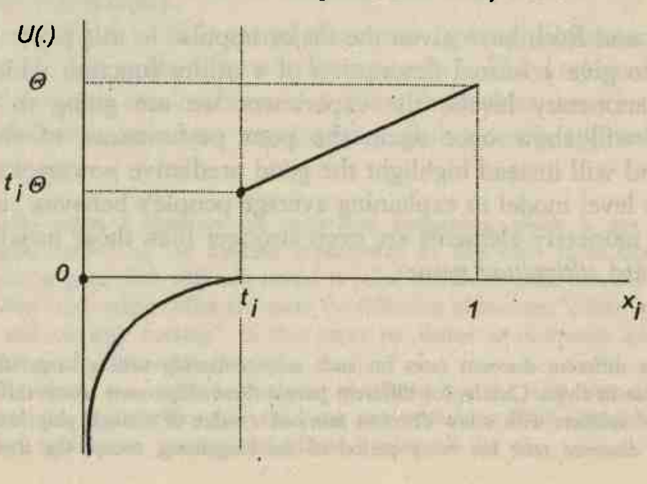
Bargaining can involve psychological elements, which play an important role in the equilibrium solution. Of the two parts one can usually suffer of a strategic disadvantage (e.g. weakness of the union power, inefficiency in production, etc.). So people with the strategic disadvantage recognise that the other part will gain more from the bargain, but they do not want to lose *too much*. In other words, they can decide that there exists a monetary threshold level t^i ($i = 1, 2$), with $0 \leq t^i \leq 1$, such that any offer below this threshold is refused because it is like an *offence* to the subject. The cost of accepting this too low offer is bigger, in terms of utility levels, than the revenue of the received offer. Let x_j be the offer to player i from player j; we can state the following utility function

$$U^i(x_j, \Theta, t^i) = \begin{cases} x_j \Theta & \text{if} \quad t^i \leq x_j \leq 1 \\ \log\left[(1/t^i)\, x_j\right] & \text{if} \quad 0 > x_j < t^i \\ 0 & \text{if} \quad x_j = 0 \end{cases} \tag{3}$$

for $i, j = 1, 2$.

Figure 1 shows the behaviour of the above utility function for the relevant range of possible offers. As we can see, for a received offer lower than t^i, subject i gets a negative utility, i.e. he/she is better off by rejecting the offer and getting 0; for offers greater than t^i, his/her best strategy is accepting.

FIG. 1. A Minimum acceptance level utility function



If (3) is the subject's utility function, let r^i be the probability that player i will accept the offer x_j, with $r^i \in [0, 1]$; hence a strategy for player i is a mapping $r^i (x_j) : [0, 1] \to [0, 1]$. Given the threshold t^i we can write the following best response correspondence

$$r^{i*} (x_j) = \begin{cases} 1 & \text{if} \quad t^i < x_j \\ [0, 1] & \text{if} \quad t^i = x_j \\ 0 & \text{if} \quad t^i > x_j \end{cases} \tag{4}$$

Note that if we assume that t^i is private information, so that the game becomes a sequential game with incomplete information, then we might explain the high percentage of rejected opening offers observed in the earlier experiments. In this experiment the threshold level is private information and is evaluated for player 2 using one information obtained through the experiment: each player 2 declared, before each game, the opening offer (henceforth declared opening offer) he would have accepted in the first period.

5. *The Experiment*

The present experiment used only one treatment variable, the periods of bargaining T (with $T = 3, 7, 20$). This allows us to check people's behaviour when the bargaining period becomes longer. In addition, to strengthen the role of monetary elements in the subjects' utility function, we assume that at the last period of the bargaining, the ultimatum offer cannot be refused; therefore the player with the strategic disadvantage has a strong incentive to make an agreement before reaching the last period, otherwise he is left with nothing. In this way the potential power of the punishment ("if you ask too much I prefer that both of us will get nothing") is reduced; therefore it should be easier for the subjects to reach the game-theoretic solution, because players with the strategic advantage do not risk any amount of money at the ultimatum period, and the rival cannot use the threat to end the game with nothing. Moreover, on the one hand, if a player with strategic advantage makes a 50/50 first offer it is because he wants to be fair and not because he is afraid to end up the bargaining with nothing; on the other hand, if we eventually find some empirical supports for the existence of monetary threshold levels, the result is even more robust.

The initial value of the pie is always Lit. 100,000 in each one of the 3 games. Each subject has the same discount factor $\delta = 0.95$ for all the 3 games. Subjects cannot cooperate, they do not know their strategic counterpart and play each game with a different opponent, so that the possibility of strategie behavior is ruled out. The discount factor makes the pie shrink, so that the amount of money is reduced by 5% when the game goes to the following period. Table 1 shows the shrinking pie for the 3 games.

TABLE 1

SHRINKING PIES IN THE 3 GAMES

t	game 1	game 2	game 3
1	100,000	100,000	100,000
2	95,000	95,000	95,000
3	90,250	90,250	90,250
4		85,737	85,737
5		81,450	81,450
6		77,378	77,378
7		73,509	73,509
8			69,337
...			...
19			39,721
20			37,735

Table 2 shows the game theoretic solutions for the three games of the experiment (the fairness solution is a 50/50 sharing).

Aside from the perfect equilibrium predictions there are also a number of important qualitative predictions. First, player 2 is predicted to receive a greater pie's share when $T = 7$ than when $T = 3$. Second, when $T = 20$, there is a change in the strategic advantage of the bargaining game, and player 2 is predicted to receive more than player 1; nevertheless, player 1 is predicted to receive more in game 3 than what player 2 received both in game 1 and in game 2.

TABLE 2

GAME THEORETIC SOLUTIONS FOR THE 3 GAMES

	player 1	player 2
Game 1	95250	4750
Game 2	87094	12906
Game 3	33104	66986

Subjects were undergraduate students in economics of the Catholic University of Milan. They were told that their performances in this experiment would give them extra credits in their microeconomics exams [9]. Participants were 44 students in each game; they were assembled in a room and randomly assigned a code number; then they were divided in two groups and located in two rooms. They could not communicate with each other. People in room 1 played as player 1 in the first game, player 2 in the second game and player 1 in the third game. Subjects did not know the rival they were playing with, until the end of the experiment. The instructions which were distributed are in Appendix A. We only answered some clarifying questions and did not play a practice game at the black board. Then the bargain began.

6. *Experimental Results* [10]

A. The data. – Figure 2 displays the opening offers in game 1.

FIG. 2. Opening offers in game 1

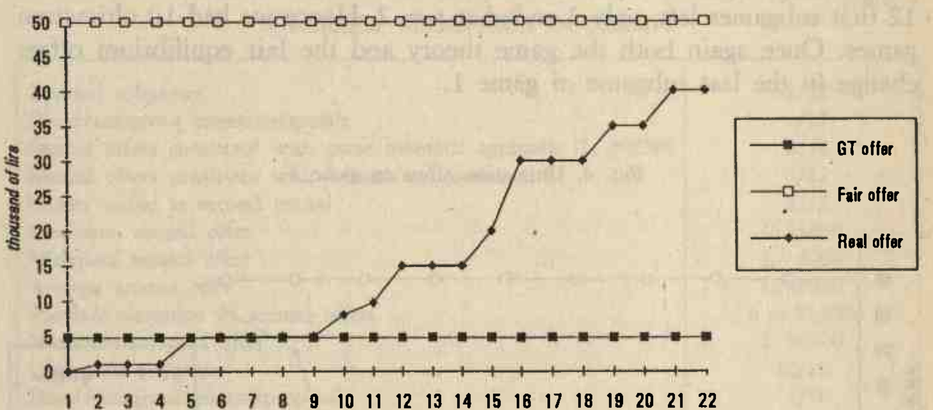
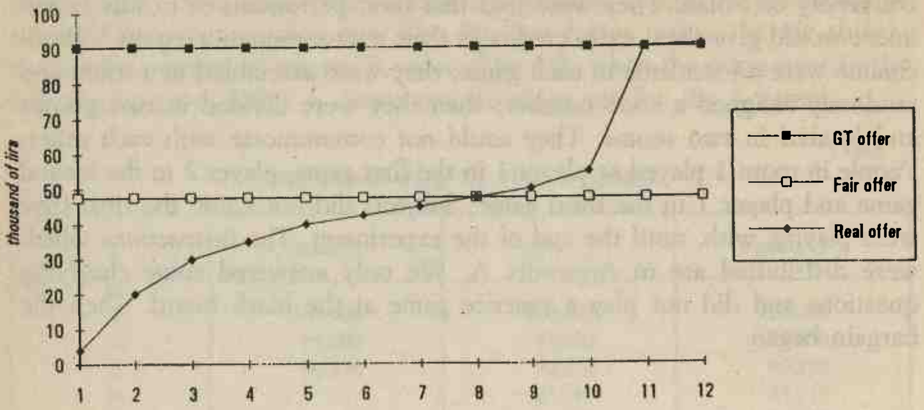


Figure 3 shows instead the second offers in game 1. As we can see, only 10 out of 22 subject interactions ended at the first period of this game,

[9] We did not run the experiment with money because it was a pilot experiment. However, the incentive of extra marks in the exams of the microeconomics course was strong enough for the subjects to play with motivation; the same real pay off system was used in the GUTH et al. (1987, p. 373) experiment.

[10] The full results are reported in Appendix B.

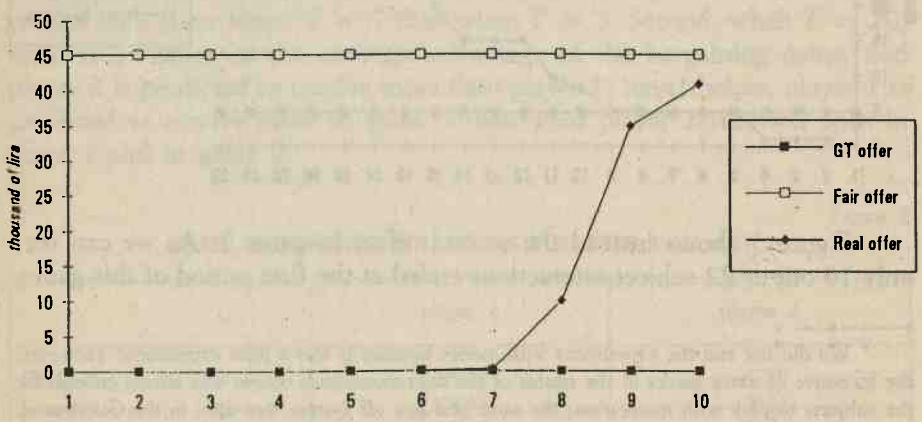
FIG. 3. Second offers in game 1



as both the game theory and fairness approach predict. Clearly, in the first subgame of game 1, both the game theory and the fair equilibrium offers change.

Finally, Figure 4 presents the ultimatum offers in game 1. Between the 12 first subgames left, only 2 ended at $t = 2$. Hence we had 10 ultimatum games. Once again both the game theory and the fair equilibrium offers change in the last subgame of game 1.

FIG. 4. Ultimatum offers in game 1



To sum up, in game 1 ($T = 3$) only 5 games out of 22 had a first offer consistent with the game theoretic predictions [11]. Only 1 of these consistent opening offers were accepted by player 2. The game theoretic predictions have therefore a quite poor performance in this game with a short bargaining period. 0 games out of 22 show an opening offer which tends toward a 50/50 sharing. Hence the fairness approach shows an even worse performance than the game-theoretic one. Table 3 shows the check of the predictions of the theoretical approaches in game 1.

TABLE 3

CHECK OF PREDICTIONS IN GAME 1

Opening offers consistent with game theoretic approach (L. 4750)	5/22
Opening offers consistent with fairness approach	0/22
Games ended at first period	10/22
Maximum opening offer	L. 40000
Minimum opening offer	L. 0
Average opening offer	L. 15930
Standard deviation of opening offers	$\sigma = 13693.1$

TABLE 4

SUBGAMES' BEHAVIOUR IN GAME 1

2-period subgames	12/22
Disadvantageous counterproposals	1/12
Second offers consistent with game theoretic approach (L. 90250)	2/12
Second offers consistent with fairness approach	3/12
Games ended at second period	2/12
Maximum second offer	L. 91000
Minimum second offer	L. 4060
Average second offer	L. 45880
Standard deviation of second offers	$\sigma = 83.459$
Minimum accepted offer	L. 90500
Ultimatum subgames	10/22
Disadvantageous counterproposals	1/10
Ultimatum offers consistent with game theoretic approach (L. 0)	7/10
Ultimatum offers consistent with *fairness* approach	1/10
Maximum ultimatum offer	L. 41000
Minimum ultimatum offer	L. 0
Average ultimatum offer	L. 8625
Standard deviation of ultimatum offers	$\sigma = 47.562$

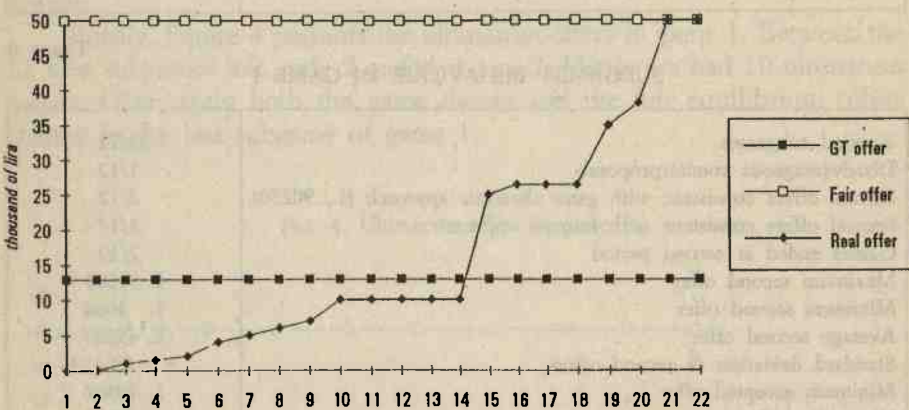
[11] We considered consistent with game-theoretic predictions an offer included in the 5% confidence interval with the game theory offer as central value. The same confidence interval is considered for the *fairness* approach.

As we can see another prediction that does not find support with the experimental data is that only 10 games ended at the first period. For every rejection the game enters in a subgame. In game 1 we have 2-period and ultimatum subgames. The behaviour in these subgames is analysed in Table 4.

The data show that in the subgames the amount of disadvantageous counterproposals is clearly small. Subjects therefore tend to behave taking into account the percentage of the pie to divide, but also they care about the absolute values. There is no evidence of an increasing consistency of the game theoretic predictions when we look at the 2-period subgame: only 2 offers out of 12 are in line with the Rubinstein approach. This percentage increases in the ultimatum game, but this should be quite obvious; nevertheless 1 offer clearly shows a desire to play fairly.

Figures 5 and 6 display the opening and second period offers in game 2.

FIG. 5. Opening offers in game 2



In game 2 ($T = 7$) no offer out of 22 is consistent with the game theoretic predictions; the number of offers in line with the fairness approach is instead greater (2/22) (see Table 5). Hence, according to the theories received from the literature, if we increase the bargaining period, people's behaviour seems to be less "rational" than in the short-run.

Even in game 2 both approaches fail to predict the period where the game ends up: only 5 games out of 22 finish in the first period. Table 6 sums up the behaviour in the subgames.

There is a feature of subjects' behaviour in the subgames of game 2

FIG. 6. Second offers in game 2

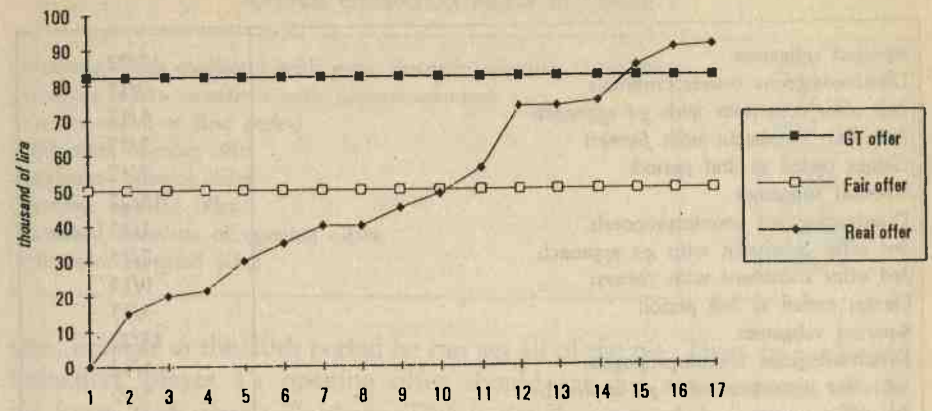


TABLE 5

CHECK OF PREDICTIONS IN GAME 2

Opening offers consistent with game theoretic approach (L. 12906)	0/22
Opening offers consistent with *fairness* approach	2/22
Games ended at first period	5/22
Maximum opening offer	L. 50000
Minimum opening offer	L. 0
Average opening offer	L. 16090
Standard deviation of opening offers	σ = 15580.1
Minimum accepted offer	L. 2000

that it is worthwhile to point out: the more players go ahead in the bargaining, the more people tend to follow the game theoretic predictions, and the less they care about any degree of *fairness* toward the rival. For instance, in the 4-period subgames, about 40 percent of the offers were in line with the game theoretic solution; almost the same percentage is observable in the 2-period subgames. The percentage of *fair* offers decreases instead to nothing from the third stage (5-period subgames).

The opening offers in game 3 are reported in Figure 7.

In game 3 (T = 20) the performance of the game theoretic approach becomes even poorer, as it is shown in Table 7. As before no opening offer at all is consistent with the perfect equilibrium predictions; moreover, the data show a very important feature of the bargaining behaviour: the longer is the bargaining period the more people do not recognise who has the strategic advantage in the game. In game 3 player 2 has the strategic advan-

TABLE 6

SUBGAMES' BEHAVIOUR IN GAME 2

6-period subgames	17/22
Disadvantageous counterproposals	0/17
2nd offer consistent with *g-t* approach	1/17
2nd offer consistent with *fairness*	2/17
Games ended at 2nd period	2/17
5-period subgames	15/22
Disadvantageous counterproposals	1/15
3rd offer consistent with *g-t* approach	2/15
3rd offer consistent with *fairness*	0/15
Games ended at 3rd period	3/15
4-period subgames	12/22
Disadvantageous counterproposals	1/12
4th offer consistent with *g-t* approach	5/12
4th offer consistent with *fairness*	0/12
Games ended at 4th period	2/12
3-period subgames	10/22
Disadvantageous counterproposals	0/10
5th offer consistent with *g-t* approach	1/10
5th offer consistent with *fairness*	0/10
Games ended at 5th period	5/10
2-period subgames	5/22
Disadvantageous counterproposals	0/5
6th offer consistent with *g-t* approach	2/5
6th offer consistent with *fairness*	0/5
Games ended at 6th period	2/5
Ultimatum subgames	3/22
Disadvantageous counterproposals	0/3
7th offer consistent with *g-t* approach	3/3

FIG. 7. Opening offers in game 3

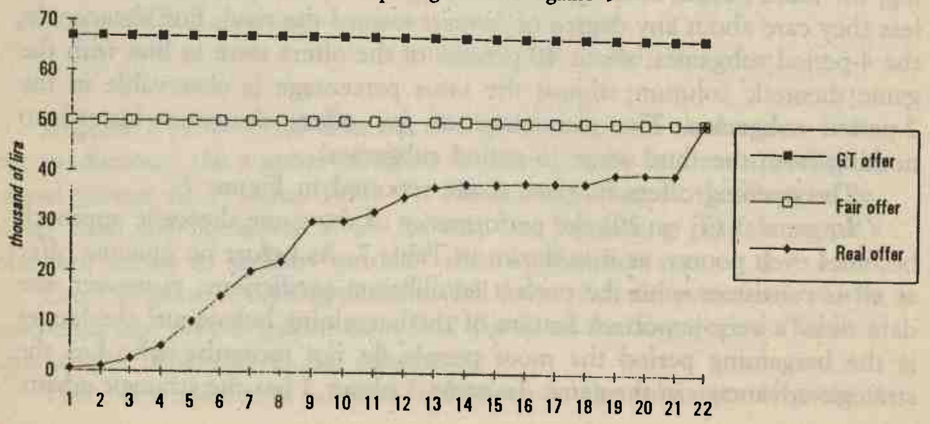


TABLE 7

CHECK OF PREDICTIONS IN GAME 3

Opening offers consistent with game theoretic approach (L. 61380)	0/22
Opening offers consistent with *fairness* approach	1/22
Games ended at first period	6/22
Maximum opening offer	L. 50000
Minimum opening offer	L. 500
Average opening offer	L. 27245
Standard deviation of opening offers	$\sigma = 14778.7$
Minimum accepted offer	L. 20000

tage, because at the 20th period he can get all of the pie. Then, by backward induction, player 1's opening offer should ask for a percentage of the pie lower than player 2's share. This is not the case of the present experiment, where the average opening offer in game 3 is L. 27245 (i.e. player 1 wants to keep L. 72755).

The *fairness* approach also has a very poor performance. Only 1 offer out of 22 is on line with this approach; as before, very few games end up at first period. Table 8 analyses the subgames' behaviours.

TABLE 8

SUBGAMES' BEHAVIOUR IN GAME 3

Games ended within 3 periods	15/22
Offers consistent with *g-t*	0/47
Offers consistent with *fairness*	8/47
Games ended within 10 periods	20/22
Offers consistent with *g-t*	6/31
Offers consistent with *fairness*	5/31
Games ended within 18 periods	22/22
Offers consistent with *g-t*	5/12
Offers consistent with *fairness*	0/12

NOTE: No disadvantageous counterproposals in any subgames.

Subgames' behaviour in game 3 can be separated in three parts: during the first three periods, there is a low percentage of offers consistent with the game theoretic approach; in the same periods players tend more to play *fair* than in the following periods. From period 4 to period 10, people generally tend to follow the game theoretic predictions more and to keep the same degree of *fairness*. In the remaining period, the two subgames exhibit a dominance of the game theoretic approach and its good predictive power.

One feature is relevant: players 2 seem to follow the game theoretic predictions more than players 1: this may be due, on the one hand, to the strategic advantage player 2 knows to have, and, on the other hand, to player 1's desire to reduce this advantage, making offers which, if player 2 becomes impatient, are more profitable for himself than in the game theoretic solution. Once again, there are no disadvantageous counterproposals.

TABLE 9

TOTAL PREDICTED AND REAL EARNINGS

	game theory	*fairness*	real
Players 1:			
game 1	2095500 (95250)	1100000	1841250 (83693.2)
game 2	1916068 (87094)	1100000	1632027 (74183.0)
game 3	728288 (33104)	1100000	861000 (39136.4)
Players 2:			
game 1	104500 (4750)	1100000	251250 (11420.5)
game 2	283932 (12906)	1100000	284530 (12933.2)
game 3	1471712 (66896)	1100000	1032000 (46909.1)
Total players:			
game 1	2200000	2200000	2092500
game 2	2200000	2200000	1916557
game 3	2200000	2200000	1893000

NOTE: per-player earning in parenthesis.

Table 9 shows another important characteristic of this experiment: only players with the strategic disadvantage have gained more than what is predicted in the game theoretic solutions; while players with the strategic advantage did not fully exploit it and gained less than in the game theoretic equilibrium.

Moreover, players as a whole gained less than what was predicted in both approaches; this increases the probability that non-monetary elements, together with monetary ones, play a crucial role in this game, as we will see later.

Another important (qualitative) prediction of the game theoretic approach fails the test with this experiment: Table 10 shows the comparison of the average opening offers between the different games, in order to check that the average opening offer in game 1 should be lower than the average

TABLE 10

CHECK OF QUALITATIVE PREDICTIONS OF THE THEORY

Differences across games in mean opening offers to player 2				
	$x-y$	t-ratio	degree of freedom	$t(\alpha) = 0{,}95$
Game 1 - Game 2	−168.32	−0.0371	21	2.08
Game 2 - Game 3	−11153.95	−2.3802	21	2.08
Game 1 - Game 3	−11322.27	−2.5752	21	2.08

NOTES: x = average opening offer in the first game; y = average opening offer in the second game; $t = (x - y)/\sqrt{(s_x^2 + s_y^2)}$, where s = standard deviation, from the Behrens' test of mean difference from 2 different samples (but n equal in both samples); degree of freedom = t_{n-1}.

opening offer in game 2, and so on. Moreover, player 1 should receive (on average) less than player 2 in game 3, but more than what player 2 received in the previous games.

First we note that the difference in the mean opening offers to player 2 in game 1 and 2 is negative (as expected) but is not significant for a confidence interval of 95 percent. The second and the third comparisons (game 2-game 3, game 1-game 3) are instead significant, but, while this is a good test for the first comparison, it is against the prediction for the latter one. We have already seen that the average earning of player 1 in game 3 is bigger than the average earning of player 2, and this is against the theory. Hence the significance of the test in the latter case confirms its poor performance.

Table 11 shows the covariance between the opening offers and the final earnings of both players, so we can identify the correlation between these variables.

It is quite interesting to note that while the correlation coefficient between offered/earning and real/earning is positive and close to one in the first two games (as expected), the same coefficient changes of sign and is close to zero in game 3; this means that while in the first two games the real earning is not very different from what players were thinking to realise with their opening offers, in game 3 there is a big difference between people expectations and real earnings. This implies two possibilities in explaining people's rationality: either they play the wrong strategy or they made an

TABLE 11

COVARIANCES BETWEEN OFFERS AND EARNINGS

	covariance	correlation
Game 1		
earn1off - earn1real	144.84	0.77
earn2off - earn2real	124.57	0.67
Game 2		
earn1off - earn1real	111.65	0.60
earn2off - earn2real	177.13	0.71
Game 3		
earn1off - earn1real	– 121.03	– 0.38
earn2off - earn2real	– 87.56	– 0.46

NOTES: *earn1off* = player 1's earning if his first offer is accepted by player 2; *earn1real* = player 1's real earning; *earn2off* = player 2's earning if he accepts player 1's first offer; *earn2real* = player 2's real earning.

opening offer just to try to test the rival's reaction. Rival's reaction can play a crucial role in this bargaining game: if the rival thinks that the received opening offer is too low (as we will see later) then he can react punishing player 1 even if this means that he will gain less. This is part of the non-monetary elements in people's utility function. Hence opening offers are used to complete player 1s' private information.

Simple OLS regressions can help to further explain the data. Tables 12, 13 and 14 display the regressed coefficients for offered/earnings and real/earnings (*t*-ratios in parentheses). The results are in line with the correlation analysis: in game 1 and 2 all coefficients are as expected and significant; in game 3 the sign of the coefficients is different from the ones predicted by the theory (aside from the last equation in game 3). Hence these results confirm the above arguments.

The best explanation of the data is obtained (as expected) by fitting the real earnings of player 1 with the real earnings of player 2; meanwhile most of the regressed coefficients are significant for a confidence interval of the *t*-distribution equal to 0.95.

To sum up, we can state that the economic analysis of the data produced by the experiment does not support both the theories present in the literature; game theory and *fairness* predict different equilibria of the game,

TABLE 12
OLS SIMPLE REGRESSIONS FOR PLAYERS' EXPECTED AND REAL EARNINGS. GAME 1 [12]

dependent variable	constant	independent variable	R^2
earn1real	*earn1off* 18.74 (1.54)	0.77 (5.43)	0.59
earn2real	*earn2off* 0.37 (0.10)	0.71 (4.04)	0.45
earn1real	*earn2off* 95.15 (28.79)	– 0.74 (– 4.55)	0.50
earn1real	*earn2real* 94.20 (72.44)	– 0.07 (– 12.81)	0.89

TABLE 13
OLS SIMPLE REGRESSIONS FOR PLAYERS' EXPECTED AND REAL EARNINGS. GAME 2

dependent variable	constant	independent variable	R^2
earn1real	*earn1off* 35.58 (3.05)	0.45 (3.70)	0.36
earn2real	*earn2off* 1.18 (0.33)	0.72 (4.57)	0.51
earn1real	*earn2off* 81.58 (26.68)	– 0.45 (– 3.37)	0,36
earn1real	*earn2real* 82.09 (41.44)	– 0.61 (– 6.33)	0.66

[12] One of the main goal when designing an experiment is to produce data which usually are not available at the micro-level. Later any quantitative method can be applied in order to explain these data.

TABLE 14

OLS SIMPLE REGRESSIONS FOR PLAYERS' EXPECTED AND REAL EARNINGS. GAME 3

dependent variable	constant	independent variable	R^2
earn1real	*earn1off* 79.42 (3.57)	−0.55 (−1.84)	0.14
earn2real	*earn2off* 57.83 (10.98)	−0.40 (−2.36)	0.21
earn1real	*earn2off* 24.04 (26.68)	2.58 (0.55)	0.14
earn1real	*earn2real* 85.81 (5.79)	−0.99 (−3.26)	0.34

a different level of total earnings, and different covariances between offers and real payoffs when the strategic advantage in the game changes from one player to another. These arguments are a strong incentive to search for an alternative explanation of the equilibrium agreements obtained in the experiment, where non-monetary elements involved in the game are mixed up with monetary ones.

As a first test of a minimum acceptance level utility function we asked player 2 to indicate the threshold level t^2 at the beginning of each game (this was not revealed to player 1). These estimations of players 2's minimum threshold level are reported in the last column of the tables of results (marked as 2l) in Appendix B. Table 15 shows that the behaviour of subjects such as player 2 is highly coherent with these estimates.

As we can see, the performance of the minimum acceptance level approach is extremely high: in game 1 it explains more than 80% of player 2's experimental behaviours relative to the opening offers, and 75% of the following counteroffers. In game 2 the performance is still very high, with a peak of 94.1% of consistent counteroffers in period 2; the predictive power becomes lower as the game goes on, but it is still greater than the previous theories. In game 3 again we have a very good performance: it is worth to note that the peak of all the 3 games is reached when the threshold is used to explain player 2's behaviour at the opening offers (95.2%) in game 3. It is important that high consistencies are tested for the first periods in all the

TABLE 15

PLAYER 2 BEHAVIOURS CONSISTENT WITH MONETARY THRESHOLDS IN THE 3 GAMES [13]

Percentage of player 2's accepted/rejected offers and counteroffers consistent with t' Game 1										
periods										
1	2									
81.8	75									
Game 2										
periods										
1	2	3	4	5	6					
81.8	94.1	80	36.4	60	60					
Game 3 [14]										
periods										
1	2	3	4	5	6	7	8	9	10	11 [15]
95.2	93.3	62.5	100	66.6	100	66.6	100	100	100	0

3 games: people prefer to reject an offer and incur in the monetary losses of a shrinking cake rather than accepting too low an offer.

Hence we can state that this first attempt to include the psychological effects in a bargaining model to explain people's behaviour seems to be very encouraging, and worthwhile to be deepened in future experiments.

[13] Consistency is tested as follows: in each period we check whether player 2's accepted/rejected offer is higher/lower than the threshold level (computed as a percentage of the monetary pie in each period, so that it is fixed for all the bargaining length), and whether player 2's counteroffer leaves to him/her a share of the pie bigger than the threshold.

[14] In this game only 21 bargains were available for this test.

[15] In game 3 only one bargain was still on at period 11: it lasted until period 14 and behaviour is inconsistent with the threshold for $t = 13$; moreover player 2 managed, in the end, to gain more than the threshold level.

7. *Summary and Conclusions*

This experiment has tested Rubinstein's (game theoretic), Selten and Roth's (fairness) theories and a model of *minimum acceptance level* to sequential bargaining on 22 subjects. The experiment was divided into 3 games, with different numbers of periods in each game. Both the approaches received from the literature show a poor performance when the predicted equilibrium solutions and the predicted offers are compared with the real ones. The performance becomes worse when the period of possible bargaining becomes longer. When people can bargain over 20 periods we observed that even the strategic advantage of the game is not immediately recognised, with different correlation indexes between real and offered earnings in respect to the previous (shorter) games.

These results confirm the poor performance, usually reported by the literature, of the approaches based only on a monetary utility function. Hence this paper contrasts with Binmore et al. (1985), who tested a good performance of the Rubinstein's approach in their experiment, and it is instead in line with the results obtained by Güth et al. (1982), Neelin et al. (1988) and Ochs et al. (1989). Binmore observed that when the punishment cost of the player with strategic disadvantage becomes large, then the experimental solutions approach the game theoretic one. This result is not obtained in the present experiment, where we observed a poorer performance of the game theoretic approach when the punishment cost becomes large. There is instead a result in common with Ochs: the test of the *minimum acceptance level* model, which involves non-monetary elements by introducing a minimum acceptance threshold in the subjects' utility function, improves in a consistent way the predicted power of the theory: on average, over the 3 games, more than 2/3 of player 2's experimental behaviour is explained by this model. This gives a strong incentive to extend this line of research in future experiments, perhaps involving an introductory stage where subjects have to declare their monetary threshold.

APPENDIX A

Instructions for participants

The experiment deals with sharing an amount of money between two people. Every subject will play this game with another one, but without meeting each other. The experiment is in three games: in game 1 the bargain can last 3 periods; in game 2 the bargain can last 7 periods; in game 3 the bargain can last 20 periods. In each game you will begin with an amount of money to share equal to L. 100000; if the opening offer is not accepted in the first period, the next one the amount of money to divide will be equal to L. 95000. The more the bargain goes on, the more the amount of money to share will be reduced.

You will play some game as player 1 and some game as player 2; if you are player 1, you will receive a piece of paper in the first period; you will write on it the amount of money you offer to player 2. Then the paper goes to player 2; if you are player 2, you will receive the offer from player 1. Then you can decide if you accept it, and the game ends with the accepted division of money, or if you reject the offer. If you reject it, you will write on the paper the offer you make to player 1 of the amount of money to be shared in the second game. Remember that this last offer belongs to another period, so that the amount of money to split is lower. Then the paper goes back to player 1; he can accept or reject the offer. If he accepts, the game ends; if he rejects, it is again her/his turn to make a new offer (which again belongs to the following period). And so on until you reach an agreement.

In game 1, you can go ahead with the above alternation, for three periods; in period 3, the amount of money to share is L. 90250. Careful: at this period, player 2 cannot reject player I's offer. So player 2 will receive the offer, and can only know what is left of the pie to him.

The same situation will happen in game 2, if you do not reach an agreement before period 7, and in game 3, if you do not reach an agreement before period 20.

Notice: If you are player 2, at the beginning of each game you have to write on a piece of paper the minimum amount of money you would have accepted as the first period offer, and give it to the experimenter. This amount of money is the minimum amount of the hole money you want to get. This is not a commitment, so later you can accept anything lower than this whenever you want. Have a good game.

APPENDIX B

Table 16

BARGAININGS IN GAME 1 (Italian lira)

bargain \ period	I	II	III	21
1	5000	–	–	1000
2	35000	40000	41000	40000
3	40000	–	–	45010
4	30000	–	–	9000
5	30000	–	–	25000
6	39990	47500	250	50000
7	15000	–	–	1000
8	5000	91000	–	9000
9	9750	–	–	5000
10	30000	45000	35000	40000
11	35000	55000	10000	45000
12	20000	–	–	0
13	15000	20000	0	20000
14	15000	30000	0	17000
15	1000	–	–	1
16	4750	–	–	20000
17	0	4060	0	800
18	1000	90500	–	8000
19	5000	35000	0	5000
20	5000	50000	0	0
21	8000	42500	0	50000
22	1000	–	–	1000

Table 18

BARGAININGS IN GAME 3 (thousands of Italian lira)

period / bargain	I XII	II XIII	III XIV	IV	V	VI	VII	VIII	IX 21	X	XI
1	15 17	10 34	20 12	20 –	22 –	25 –	25 –	27 –	24 37.7	24 –	25 –
2	38 –	5 –	50 –	– –	– –	– –	– –	– –	– 95	– –	– –
3	5 –	7 –	53 –	6 –	50 –	22.3 –	– –	– –	– 50	– –	– –
4	0.5 –	5 –	84.2 –	– –	– –	– –	– –	– –	– 38	– –	– –
5	38 –	5 –	52.6 –	4 –	44 –	3 –	36 –	0.01 –	40 80	13.0 –	– –
6	38 –	– –	– –	– –	– –	– –	– –	– –	– 37.7	– –	– –
7	10 –	25 –	– –	– –	– –	– –	– –	– –	– 50	– –	– –
8	39.9 –	45 –	– –	– –	– –	– –	– –	– –	– 45	– –	– –
9	40 –	– –	– –	– –	– –	– –	– –	– –	– 37.7	– –	– –
10	37 –	47.2 –	– –	– –	– –	– –	– –	– –	– 37.7	– –	– –
11	32 –	– –	– –	– –	– –	– –	– –	– –	– 10	– –	– –
12	20 –	– –	– –	– –	– –	– –	– –	– –	– 15	– –	– –
13	50 –	– –	– –	– –	– –	– –	– –	– –	– 40	– –	– –
14	37.7 –	– –	– –	– –	– –	– –	– –	– –	– 37	– –	– –
15	30.1 –	50 –	– –	– –	– –	– –	– –	– –	– 37.7	– –	– –
16	2.5 –	45 –	– –	– –	– –	– –	– –	– –	– 40.	– –	– –
17	30 –	50 –	– –	– –	– –	– –	– –	– –	– 35	– –	– –
18	40 –	55 –	– –	– –	– –	– –	– –	– –	– 40	– –	– –
19	22 –	25 –	40 –	30 –	51 –	– –	– –	– –	– 60	– –	– –
20	37.7 –	20 –	44 –	30 –	41 –	20 –	40 –	15 –	– 45	– –	– –
21	1 –	10 –	3 –	20 –	2 –	21 –	– –	– –	– 37.8	– –	– –

Notes: first row periods from I to X. Second row periods from XI to XIV. Last column in second row player 2's threshold.

TABLE 17

BARGAININGS IN GAME 2 (Italian lira)

period / bargain	I	II	III	IV	V	VI	VII	21
1	4000	21500	750	73509	941	74000	–	20000
2	5000	40000	4900	40000	2500	31000	0	35000
3	25000	35000	250	74000	5000	–	–	30000
4	10000	20000	9000	10000	10	25000	0	40000
5	10000	45000	8156	8573	3869	–	–	40000
6	7000	85000	10000	73237	50	3869	0	10000
7	35000	–	–	–	–	–	–	26491
8	26450	–	–	–	–	–	–	26480
9	26492	30000	16740	–	–	–	–	5000
10	38160	56000	15000	61737	2000	–	–	42000
11	1500	49000	250	60015	200	73509	–	39900
12	6000	73509	10000	–	–	–	–	20000
13	50000	–	–	–	–	–	–	18000
14	26491	40000	0	75000	–	–	–	20000
15	0	90250	–	–	–	–	–	4750
16	1000	91000	–	–	–	–	–	4000
17	50000	–	–	–	–	–	–	4000
18	100	73509	6500	73509	7000	–	–	25000
19	10000	0	20000	0	7000	–	–	1000
20	2000	–	–	–	–	–	–	4000
21	10000	15000	40000	–	–	–	–	20000
22	10000	75000	8000	83000	–	–	–	20000

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RILEVANZA EMPIRICA DI TEORIE DIFFERENTI: UN APPROCCIO SPERIMENTALE AI GIOCHI DI CONTRATTAZIONE

Nelle scienze economiche il comportamento individuale è razionale per ipotesi: talvolta l'idea di razionalità degli individui è diversa da quella prevista dagli economisti, però i modelli teorici devono necessariamente essere costruiti sulla base di un concetto di razionalità. In letteratura esiste una crescente domanda di spiegazione delle origini della razionalità individuale, e di verifica empirica di modelli teorici ben definiti ma che spesso non sembrano avere una rilevanza empirica.

Gli *esperimenti economici* sono uno strumento a disposizione degli economisti per verificare le teorie sui comportamenti strategici e individuali e per studiare le decisioni economiche: questo articolo mostra la rilevanza empirica di due consolidate teorie sulla contrattazione. La capacità predittiva in laboratorio di entrambe le teorie è molto limitata, e sembra pertanto opportuno ricercare delle spiegazioni alternative del comportamento degli individui.

In questo senso viene costruito un modello teorico basato sull'ipotesi di esistenza di un livello minimo di accettazione da applicare alla contrattazione. Tale modello mostra una migliore adattabilità ai dati sperimentali delle precedenti teorie; in questo senso, esso sembra poter (almeno parzialmente) riempire il gap esistente tra comportamento razionale *teorico* ed *effettivo*.

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HEDGING COTTON PRICE RISK IN FRANCOPHONE AFRICAN COUNTRIES

by
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I. *Introduction*

The volatility of primary commodity prices in recent years has resulted in substantial risks for exporting countries. International Commodity Agreements between exporting and importing nations have sought to stabilize commodity export prices but these agreements have not been successful. Cotton prices, like the prices of most other primary commodities, have been very volatile in international markets. The volatility of cotton prices in recent years has resulted in substantial risks for cotton producing countries many of which are less developed countries (LDCs). The main cotton producers in the Francophone African (FPA) [1] region have been especially hard hit by these price fluctuations since a major share of their agricultural export revenues is derived from cotton. At present, the only risk management instrument used by Francophone African countries is forward sales and typically between a fourth and a third of the cotton is sold forward. This, however, leaves a significant portion of cotton exposed to price risk. Thus, there is need for some form of commodity risk management.

Futures markets offer an alternative method of stabilizing export revenues in the short run through hedging [2]. This paper uses portfolio theory

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[1] The main cotton producers in this region include Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Côte d'Ivoire, Mali, Senegal and Togo.

[2] The usefulness of futures markets in stabilizing export revenues has been examined by several authors. See for instance, ROLFO (1980), GEMMILL (1985), SHEALES and TOMEK (1987), OUATTARA, SCHROEDER, and SORENSON (1990), and VARANGIS, THIGPEN, and SATYANARAYAN (1994).

to examine the potential for reducing risk for FPA cotton exports through hedging in the futures market. We compare three strategies – a risk management strategy based on an optimal ex-ante hedging strategy, a naive hedging strategy and no hedging. We also examine the effect of risk aversion on the hedging decision and estimate the opportunity costs of hedging by considering the trade-off between risk and return in terms of a portfolio opportunity frontier.

This paper is organized as follows. Section 2 discusses the cotton marketing system in FPA countries and the need for effective commodity price management. Section 3 examines the effectiveness of different hedging strategies and analyzes the effect of risk aversion on the hedging decision. Estimates of the opportunity costs of hedging are also provided. Section 4 concludes the paper.

II. *The Cotton Marketing System in Francophone African Countries*

The only risk management instrument used by FPA countries is forward export sales but since only between a fourth and a third of the cotton is sold forward by the beginning of the crop year in mid-July (see Table 1), a significant portion of cotton exports is exposed to price risk. Under the old cotton marketing system in FPA countries the major part of this price risk was ultimately borne by the government. FPA countries depended heavily on the use of stabilization funds which, in principle, accumulated funds during seasons of relatively high cotton prices to cover deficits during seasons of low prices. In practice, however, the available funds were often insufficient to support producer prices during low price periods forcing governments to assume the deficit and ultimately the risk.

Following massive disasters to the cotton marketing system during the period of low cotton prices in the mid-1980's, substantial reforms were implemented. These reforms were country specific but there were common elements. Essentially, they aimed at introducing flexibility in the producer pricing arrangement by linking the price to actual export revenues. The function of the parastatal marketing organizations were also revamped so that they were required to operate with risks and incentives similar to private marketing organizations. In effect, these reforms shifted some of the price risk from the government to producers and marketing organizations.

As economic reforms progress in FPA countries the need for effective commodity price management will increase. Given the limited coverage provided by forward sales, futures hedging can play a significant role in

TABLE 1

SEASONAL COTTON EXPORT COMMITMENT OF FRANCOPHONE AFRICAN COUNTRIES - 1989/90 TO 1992/93

	Marketing Year							
	1989/90		1990/91		1991/92		1992/93	
Volume/Share	Tons	Share	Tons	Share	Tons	Share	Tons	Share
		(%)		(%)		(%)		(%)
Sales date								
Mid-July			163	34	128	25	77	14
Mid-Aug/Sept			200	42	205	40		
Mid-Nov	272	60	233	48	260	50	182	34
Mid-Jan	296	65	309	64	327	63	305	56
Mid-March	413	91	388	81	469	90	329	61
Mid-May	430	95	450	94	482	93	461	85
Crop-Year Exports	455		481		519		543 est	

SOURCE: International Cotton Advisory Committee.

commodity risk management. Managing commodity price risk through futures markets also provides certain advantages. Forward sales require marketing agents to find a buyer which at times may be difficult. Since futures markets place no such restriction they provide greater flexibility to marketing organizations. Moreover, futures markets provide enough liquidity for small cotton producers such as FPA countries [3]. Use of futures hedging can also make withdrawals from or accumulations into existing stabilization funds more predictable [4].

In a liberalized marketing system, the majority of price risk is likely to be borne by the producer. Moreover, with privatized cotton export marketing the use of forward sales is likely to diminish because of credit risk.

[3] The total annual production of cotton in FPA countries is about 543,000 tons (1992/93). The New York Cotton Futures Market trades 260,000 tons daily, the majority of which are concentrated in the four nearby contracts. Liquidity is thus not an issue.

[4] LARSON and COLEMAN (1991) show that the use of market-based financial instruments such as options and futures can increase the probable life of stabilization funds.

Private exporters, particularly newly established ones, are perceived as being a greater risk than parastatals. Futures contracts can thus substitute for forward export sales. Domestic forward markets can, however, still provide a useful function by transferring risk from producers to intermediaries who can then pool the risks of a large number of producers and hedge it in international futures markets. Thus, domestic forward markets provide mechanisms for internal risk sharing while futures markets externalize the risk by placing it in international markets which are more capable of absorbing it. This combination of domestic forward and international futures markets is likely to provide the most transparent and efficient system of risk sharing and short-run price stabilization [5].

III. *Risk Aversion and Return-risk Trade-offs*

The FPA hedging decision can be thought of as a portfolio selection problem in which the hedger selects the optimal proportions of unhedged (spot) and hedged (futures) output [6]. The FPA portfolio can be represented as:

$$ER_p = Q_u E(S_{t+1} - S_t) + Q_h E(F_{t+1} - F_t) \tag{1}$$

where:

ER_p = Expected return on the hedged portfolio
Q_u = Unhedged (spot) output or output available for export
$E(S_{t+1} - S_t)$ = Expected change in the FPA export price from time t to time $t + 1$
Q_h = Hedged output
$E(F_{t+1} - F_t)$ = Expected change in the futures price from time t to time $t + 1$

At time period t, the values of S_{t+1} and F_{t+1} are unknown and these are, therefore, random variables [7]. In a short hedge, a long position in the spot

[5] CLAESSENS and VARANGIS (1993) provide a good example of such a system in their discussion of the Costa Rican coffee marketing system.

[6] In terms of conventional portfolio theory, hedged output can be thought of as a riskless asset and unhedged output as a risky asset.

[7] We have not incorporated costs into the model. These costs include brokerage fees (usually a thousandth of the contract value) and the opportunity cost of holding a margin account – i.e., the difference between the interest bearing notes of the margin account and investing somewhere else. However, these costs are considered very small.

market ($Q_u > 0$) is offset by a short position in the futures market ($Q_b < 0$). Let $h = (Q_b / Q_u)$. If the value of Q_u is set equal to 1, h can be interpreted as the hedge ratio – the percentage of the spot or cash position that is hedged in the futures market. Thus,

$$ER_p = E(S_{t+1} - S_t) - h\,E(F_{t+1} - F_t) \quad (2)$$

If the portfolio is completely hedged, that is, each unit in the spot market is hedged with a unit of futures, then $h = 1$. (This type of hedge is called a "naive hedge"). If $h = 0$, then there is no hedging and the expected return on the portfolio is simply equal to the return on the spot market.

The variance or risk of the portfolio (Var_p) is given by:

$$\mathrm{Var}_p = \mathrm{Var}(S) + h^2\,\mathrm{Var}(F) - 2h\,\mathrm{cov}(S, F) \quad (3)$$

where:

Var (S), Var (F) = variance of spot and futures price changes
cov (S, F) = covariance between spot and futures price changes

The expected utility (EU) function of FPA countries is a function of the expected return (ER_p) and variance of the portfolio (Var_p). Thus,

$$EU = E(R_p) - \lambda\,\mathrm{Var}_p \quad (4)$$

where λ is a risk aversion parameter. Higher (lower) values of λ imply higher (lower) levels of risk aversion. The model above is a mean-variance model (see Markowitz, 1959) and implicitly assumes that the hedger has a quadratic utility function or that returns are normally distributed [8]. The optimization problem is to select the hedge ratio which will maximize EU. Thus,

$$\partial EU/\partial h = -E(F_{t+1} - F_t) - 2\lambda h\,\mathrm{Var}(F) + 2\lambda\,\mathrm{cov}(S, F) = 0$$

Solving for the optimal (utility-maximizing) hedge ratio, h^{**}, from the above gives:

$$h^{**} = [\mathrm{cov}(S, F)/\mathrm{Var}(F)] + [(F_t - E(F_{t+1}))/2\lambda\,\mathrm{Var}(F)] \quad (5)$$

Let $h^* = [\mathrm{cov}(S, F) / \mathrm{Var}(F)]$. The above may then be rewritten as:

[8] Quadratic utility functions raise several theoretical problems (see ARROW, 1971) but work by LEVY and MARKOWITZ (1979) and KROLL, LEVY, and MARKOWITZ (1984) suggest that the assumption of quadratic utility is a reasonable empirical approximation.

$$h^{**} = h^{*} + ([F_t - E(F_{t+1})]/[2\lambda \ \mathrm{Var}\ (F)]) \tag{6}$$

With infinite risk aversion (i.e. $\lambda \rightarrow \infty$), the second term disappears. The first term in the equation above, h^{*}, is called the hedging component and is equivalent to the risk-minimizing hedge ratio [9]. With infinite risk aversion, the optimal or utility maximizing hedge ratio is thus the same as the risk minimizing hedge ratio (i.e. $h^{**} = h^{*}$). The second term in (6) is called the speculative component and this is inversely related to λ and positively related to the "bias" ($F_t - E[F_{t+1}]$) between the current and expected futures price. The speculative component essentially captures the effect of hedging on expected returns [10].

Table 2 reports the risk minimizing hedge ratios and contrasts the performance of four portfolios - unhedged, naive, ex-ante hedged and ex-post hedged for the years 1987-91 [11]. We assume that hedges are placed in August of each year by buying the July No.2 cotton contract on the New York Cotton Exchange and continued until June of the next year before the contract matures. The timing of the hedges approximately coincides with the cotton season in FPA countries [12].

The results in Table 2 imply that in every one of the hedges the risk of the unhedged position exceeded the risk of the ex-ante hedged position. Also, notice that the risk of the naive portfolio is less than the risk of the unhedged portfolio in four of the hedges but more than twice the risk of the unhedged portfolio for the Aug.90 hedge. This is not surprising given that naive hedges are effective only when the spot and futures commodity are identical.

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[9] Note that h^{*} is simply the slope coefficient of an OLS regression of futures price changes on spot price changes.

[10] Equation 6 also implies that if the current futures price is an unbiased estimate of next period's futures price (i.e. $F_t = E[F_{t+1}]$), the speculative component in h^{**} disappears and $h^{**} = h^{*}$. Thus in an unbiased futures market, the risk-minimizing hedge ratio is equal to the optimal hedge ratio. Also, with infinite risk aversion the optimal hedge ratio is independent of this bias. See McKinnon (1967) and Rolfo (1980).

[11] The risk minimizing hedge ratios in Table 2 were estimated using information available only up to the period in which the hedge was placed. This is much more reasonable than the ex-post approach used in much of the literature. The ex-post portfolio in Table 2 can be thought of as a benchmark to compare the performance of the other hedges since the ex-post hedge is based on complete information and thus yields the maximum amount of risk reduction.

[12] The No.2 cotton contract is based on grade 41, staple 34 (strict low middling 1-1/16 inch) cotton. The quality of FPA cotton is similar but not identical. These hedges are thus cross hedges. Also, the results do not change significantly if we select other months for the hedges. Compare, for example, Table 3 here and Table 5 in Satyanarayan et al. (1993). The timing of the hedges in both papers is different but the basic results relating to risk reduction is similar.

TABLE 2

PERFORMANCE OF HEDGED & UNHEDGED PORTFOLIOS FOR FRANCOPHONE AFRICAN COTTON

Period	Portfolio	Hedge Ratio	Return (US cents per lb.)	Variance	Risk-Reduction
		(Aug. '87 Hedge)			
May 85 - July 87	Unhedged	h = 0	-1.70	7.27	—
	Naive	h = 1	- .51	2.51	65%
	Ex-Ante Hedged	h = .23	-1.43	4.82	34%
Aug 87 - June 88	Ex-Post Hedged	h = .80	- .74	2.21	70%
		(Aug. '88 Hedge)			
May 85 - July 88	Unhedged	h = 0	1.48	6.61	—
	Naive	h = 1	.07	3.81	42%
	Ex-Ante Hedged	h = .27	1.10	5.55	16%
Aug 88 - June 89	Ex-Post Hedged	h = 1.40	- .50	3.56	46%
		(Aug. '89 Hedge)			
May 85 - July 89	Unhedged	h = 0	.32	4.54	—
	Naive	h = 1	- .25	2.32	49%
	Ex-Ante Hedged	h = .30	.14	1.81	60%
Aug 89 - June 90	Ex-Post Hedged	h = .61	- .03	0.87	81%
		(Aug. '90 Hedge)			
May 85 - July 90	Unhedged	h = 0	- .53	3.35	—
	Naive	h = 1	-1.50	7.24	-116%
	Ex-Ante Hedged	h = .32	- .84	1.65	50%
Aug 90 - June 91	Ex-Post Hedged	h = .36	- .88	1.63	51%
		(Aug. '91 Hedge)			
May 85 - July 91	Unhedged	h = 0	-1.11	6.06	—
	Naive	h = 1	- .25	3.62	40%
	Ex-Ante Hedged	h = .32	- .84	4.07	33%
Aug 91 - June 92	Ex-Post Hedged	h = .72	- .49	3.17	48%

NOTE: A negative sign for risk-reduction means that the hedge is risk-increasing rather than risk-reducing.

We also calculated the risk reduction benefits of hedging [13]. For the ex-ante hedges, these benefits range from 16% (Aug.88 hedge) to 60% (Aug.89 hedge). For the naive hedges, risk reduction ranges from 65% (Aug.87 hedge) to –116% (Aug.90 hedge). The negative sign implies that by hedging all output, the risk of the naive portfolio actually *increases* over that of the unhedged or spot position. This simply reiterates the fact that naive hedges are inappropriate for FPA cotton.

Overall, the unhedged portfolio performs better than the ex-post portfolio in terms of return [14] although, of course, the unhedged portfolio is more risky. Hedging carries an opportunity cost in terms of return and whether the hedger considers these costs reasonable or not depends upon the hedger's degree of risk aversion. We turn now to a discussion of these costs and the effect of risk aversion on the hedging decision.

We estimated ex-post optimal hedge ratios for FPA cotton at different levels of risk aversion using the July 1990 futures contract as an example. Table 3 reports optimal hedge ratios at different levels of risk aversion and the associated return and risk levels. It is clear from the table that for values

TABLE 3

OPTIMAL HEDGE RATIOS, RETURN AND RISK AT VARYING LEVELS OF RISK AVERSION

Risk Aversion Parameter λ	Optimal Hedge Ratios h**	Return (cents per lb.)	Variance
∞	.6547	0.53	3.39
10,000	.65	0.53	3.39
1,000	.65	0.53	3.39
100	.65	0.53	3.39
10	.65	0.53	3.39
1.0	.58	0.61	3.44
.10	-.12	1.41	7.83
.01	-7.05	9.40	447.02
.001	-76.36	89.25	44,365.60
.0001	-769.53	887.78	4,436,223.14

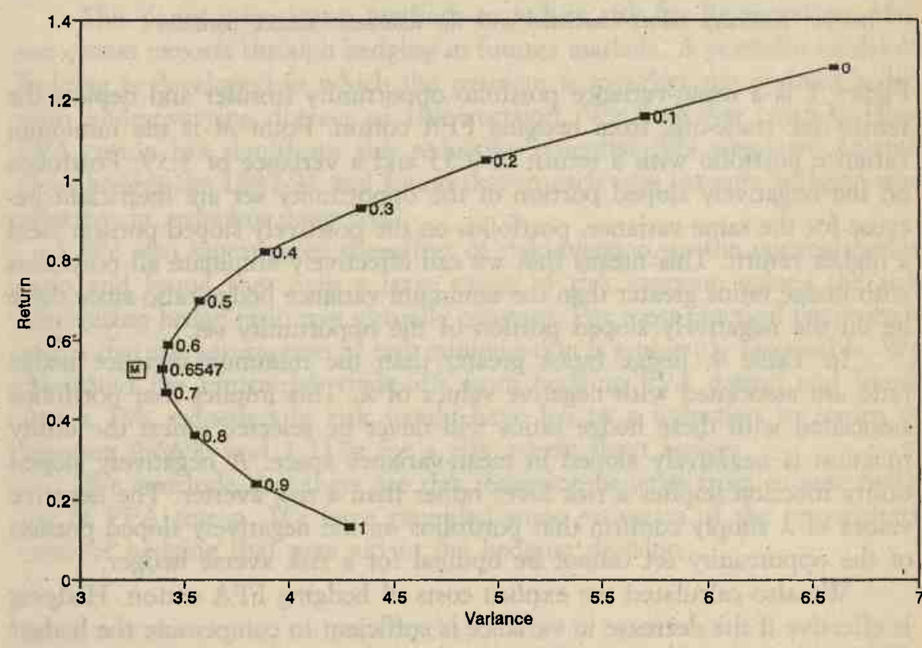
[13] The percentage reduction in risk (1- [Var (Hedged) / Var (Unhedged)] is identical to the coefficient of determination, R^2, in a regression of futures price changes on spot price changes. See EDERINGTON (1979) for a detailed derivation of the result.

[14] The ex-post portfolio lost money in all five hedges whereas the return on the unhedged portfolio was positive in two hedges and less negative than the ex-post portfolio in one hedge. Note, however, that the unhedged and ex-post portfolios are not strictly comparable since the time period covered is different for both portfolios.

of λ between 10 and infinity, the optimal hedge ratio is essentially constant implying that for these values of risk aversion the speculative component is insignificant. This result is similar to Rolfo's (1980) result on optimal hedging for cocoa producing countries and Ouattara, Schroeder, and Sorenson's (1990) work on coffee hedging for Côte d'Ivoire. At values of λ equal to or lesser than .10, the results imply that FPA countries should *buy* rather than sell futures (i.e. negative values of h^{**} imply a long position in futures). This is not a surprising result in view of the relation that existed between F_t and $E(F_{t+1})$ over the life of the July 1990 contract. Over the hedge period, the mean value of $(F_t - F_{t+1})$ was equal to -1.152 (cents per lb.). Given that the mean ex-post bias was negative, it is not surprising that at lower levels of risk aversion, the recommendation is to go net long in futures to profit from the bias.

We calculated portfolio returns and variances for hedge ratios between 0 and 1 [15]. These results are reported in Table 4 and graphed in Figure 1.

FIGURE 1. Return-risk trade-offs from hedging



NOTE: The numbers on the portfolio opportunity frontier refer to hedge ratios. *M* stands for the minimum-variance portfolio.

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[15] We confine ourselves to these hedge ratios since we wish to consider return-risk trade-offs from the perspective of short-hedging.

TABLE 4

RISK-RETURN TRADE-OFFS

Optimal Hedge Ratio	Implied Risk-Aversion Parameter λ	Return	Variance	% Reduction in Return	% Reduction in Variance	Cost
0	.1176	1.28	6.60	-	-	-
.10	.1388	1.16	5.70	9	14	.66
.20	.1694	1.05	4.94	18	25	.72
.30	.2171	.93	4.34	27	34	.79
.40	.3024	.82	3.88	36	41	.87
.50	.4978	.70	3.57	45	46	.98
.60	1.4078	.59	3.42	54	48	1.12
.6547*	∞*	.53*	3.39*	59*	49*	1.21*
.70	-1.70	.47	3.41	63	48	1.30
.80	-.53	.36	3.55	72	46	1.56
.90	-.31	.24	3.84	81	42	1.94
1.0	-.22	.13	4.29	90	35	2.57

NOTE: * indicates values associated with the minimum-variance portfolio.

Figure 1 is a mean-variance portfolio opportunity frontier and depicts the return-risk trade-offs from hedging FPA cotton. Point *M* is the minimum variance portfolio with a return of 0.53 and a variance of 3.39. Portfolios on the negatively sloped portion of the opportunity set are inefficient because for the same variance, portfolios on the positively sloped portion yield a higher return. This means that we can effectively eliminate all portfolios with hedge ratios greater than the minimum variance hedge ratio since these lie on the negatively sloped portion of the opportunity set.

In Table 4, hedge ratios greater than the minimum-variance hedge ratio are associated with negative values of λ. This implies that portfolios associated with these hedge ratios will never be selected *unless* the utility function is negatively sloped in mean-variance space. A negatively sloped utility function implies a risk lover rather than a risk averter. The negative values of λ simply confirm that portfolios on the negatively sloped portion of the opportunity set cannot be optimal for a risk averse hedger.

We also calculated the explicit costs of hedging FPA cotton. Hedging is effective if the decrease in variance is sufficient to compensate the hedger for the decrease in returns. We compared the return and risk of the unhedged position with the return and risk of the hedged positions to calculate a cost elasticity measure as follows:

Cost of Hedging = (% Reduction in Return)/(% Reduction in Risk) where

% Reduction in Return = 1 – [(Return of Hedged) / (Return of Unhedged)]

and the percentage reduction in risk is as defined previously (see footnote 13). These cost elasticities are shown in the last column of Table 4 and range from a low of .66 to a high of 2.57, with larger values implying higher costs of risk reduction. The cost associated with the minimum-variance portfolio is 1.21 which implies that a 1% reduction in risk will result in a 1.21% reduction in return [16]. Whether this is a reasonable cost of hedging or not depends upon the degree of risk aversion. The particular point on the efficient frontier where the FPA countries will choose to lie depends upon their subjective risk-return attitudes.

IV. *Concluding Remarks*

This paper investigates methods to reduce risk for Francophone African cotton exports through hedging in futures markets. A portfolio model of hedging is developed in which the problem is to select the optimal hedge ratio under varying degrees of risk aversion. We find that cross hedging FPA cotton has significant risk reduction potential. We simulated ex-ante cross hedges for 1987-91 and found that in each case, ex-ante hedging was effective in reducing price risk.

We also investigated the effect of risk aversion on the optimal hedge ratio and found that over a large range of risk aversion values the risk minimizing hedge ratio was virtually constant. For most practical purposes it seems that the assumption of risk minimization is eminently reasonable. We calculated the return-risk trade-offs from hedging FPA cotton and found that a 1% reduction in risk would have led to a reduction in return of between 0.66% and 1.21% for a risk averse short hedger.

We conclude that there are risk reduction benefits from ex-ante hedging of FPA cotton. We have provided some estimates of the opportunity costs of hedging that may aid in the hedging decision.

[16] The portfolio opportunity frontier (and thus risk-return trade-offs) will change depending on the levels, variances and covariances of spot and futures price changes and would be different in another period. The results here are indicative of the nature of the trade-offs prevailing in this market.

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COPERTURA DEL RISCHIO SUL PREZZO DEL COTONE NEI PAESI AFRICANI FRANCOFONI

Questo articolo esamina i metodi per ridurre il rischio sulle esportazioni di cotone per i paesi africani francofoni usando per la copertura un modello di portafoglio. Si trova che le coperture incrociate ex-ante sono efficaci nel ridurre il ri-

schio. Qui viene esaminato l'effetto dell'avversione al rischio sulla decisione di copertura ottimale e si trova che su un'ampia serie di valori di avversione al rischio, il tasso di copertura che minimizza il rischio è virtualmente costante. Si sono anche stimati i costi di opportunità della copertura. I risultati indicano che nel periodo campione una riduzione del rischio dell'1% avrebbe comportato una riduzione dei profitti tra 0,66% e 1,21% per un operatore avverso al rischio che si copre a breve.

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ROBUSTNESS OF GREEK BUSINESS FAILURE PREDICTION MODELS

by
CHRISTOS NEGAKIS *

1. *Introduction*

During the eighties, the Greek government put pressure on government banks to continue financing many large "ailing" firms for several years after their economic failure. The government's policy had a tremendous impact on the country's budget deficit [1]. This fact, along with losses suffered by many private banks from ailing or other failing firms, triggered the development of models which could be used to predict the deteriorating economic condition of a firm early enough to initiate successful corrective actions.

Such models have gained international acceptance by commercial bankers, investment specialists, legal analysts, government regulatory agencies, accounting auditors, and business consultants [2]. Financial companies have employed these models as a tool in advising investors whether or not a particular firm under consideration is financially sound. Therefore, such models could be useful to the banking system, corporate creditors, regulato-

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[1] The government's deficit in billion drachmas between 1980 and 1986 increased in the following order (respective years in parenthesis): 53.43 (1980), 176.81 (1981), 174-49 (1982), 283.29 (1983), 351.03 (1984), 586.57 (1985), and 519.88 (1986). The percentage of the budget deficits attributed to the "ailing" (problematic) and other government run firms were 47.2 (1980), 61.6 (1981), 36.8 (1982), 41.9 (1983), 42.0 (1984), and 46.3 (1985). Data on the deficit were extracted from the 1987 and 1988 *IFS* yearbooks, pp. 360-1 and pp. 252-53, respectively. Data on the problematic firms were extracted from *Oikonomia*, 1987, p. 8.

[2] See ALTMAN (1983) for many references in the area of predicting, avoiding, and implementing business failure prediction models.

ry agencies, and investors in Greece and the European Economic Community.

There have been several recent attempts to develop a business failure prediction model for Greek firms (e.g., Gloubos and Grammatikos 1988, Theodossiou and Papoulias 1988, and Theodossiou 1991). The aforementioned studies have used statistical models such as linear probability, linear discriminant analysis, logit, and probit. The ability of these models to predict which firms are financially distressed have been tested by using different sets of financial variables as explanatory variables. These models have been shown to be quite effective in predicting the failure of a firm. However, an issue that needs to be addressed before the models can be implemented, is their robustness over time which is the objective of this paper.

The paper is organized as follows: Section 2 provides a brief review and a comparison of previous Greek studies on the subject. Section 3 discusses a procedure for testing the robustness of business failure prediction models over time and presents the results of testing the robustness of Theodossiou's (1991) model. Section 4 illustrates the implementation of the aforementioned model. The paper ends with concluding remarks in Section 5.

2. *Recent Greek Studies*

Gloubos and Grammatikos (1988) used a sample of 30 failed and 30 healthy industrial firms collected from the period 1977-81 and fitted a linear probability, a linear discriminant, a logit, and a probit model to the data. Using stepwise discriminant analysis, they identified two profiles of variables as being the best in predicting the failure of Greek firms. The first profile included the ratios of net working capital to total assets (*NWC/TA*), gross profit (income) to total assets (*GP/TA*), and total debt to total assets (*TD/TA*). The second profile, in addition to the three previous variables, included the ratios of current assets to current liabilities (*CA/CL*), and gross profit to current liabilities (*GP/CL*). The above sets were evaluated using both the sample employed to estimate the models (estimation sample) as well as a holdout sample consisting of 24 failed and 24 healthy firms collected from the period 1982-85. The error rates of their models ranged between 3 and 17 percent in the estimation sample and between 13 and 40 percent in the holdout sample. The fact that the error rates of the models were higher in the holdout sample than in the estimation sample indicates that these models are not stationary.

In an attempt to develop a reliable failure prediction model, Theodossiou (1991) used a larger and more recent sample of firms than had been used in previous Greek studies. This sample included 54 failed firms and 309 healthy firms collected from the years 1980-83. These firms represented industries in the manufacturing sector such as food products, textiles, clothing, footwear, furniture, paper, paper articles, plastic, rubber, machinery, wood and cork, and electrical equipment. In addition, two methodological issues not adequately dealt with in previous Greek studies, were addressed: (a) the methodology used to select the explanatory variables of the models; and (b) the selection of the most appealing statistical model. The statistical models tested were the linear probability, the logit, and the probit models.

The selection of the explanatory variables of the models was based on Mallows *Cp* selection criterion (Mallows, 1973). Unlike stepwise discriminant analysis, the *Cp* criterion accounts for model mis-specification error, i.e., the error associated with the inclusion of variables that do not belong in the model. The best profile of variables included the ratios of net working capital to total assets (*NWC/TA*), net income to total assets (*NI/TA*), retained earnings to total assets (*RE/TA*), total debt to total assets (*TD/TA*), and long term debt to total assets (*LTD/TA*).

The predictive ability of the three statistical models was assessed on the estimation sample as well as on a holdout sample of 27 failed and 111 healthy firms collected from the year 1984. While all three statistical models performed well, the logit and the probit models were equivalent but superior to the linear probability model. The simplicity, however, associated with the estimation of the logit model and calculation of the logistic probabilities of failures makes the logit model more appealing. The estimated logit model, and its performance on the estimation and holdout sample were as follows [3]:

$$
\begin{array}{llll}
Z = -14.14 - 5.033\ NWC/TA & - 9.497\ NI/TA & - 9.432\ RE/TA\ + & \quad (1) \\
T\text{-value} \quad -2.89 & -1.99 & -2.61 & \\
\quad + 13.96\ TD/DA + 4.003\ LTD/TA & & & \\
\quad\quad 2.14 \qquad\qquad 1.98 & & &
\end{array}
$$

Error Rate:	Healthy Firms	Failed Firms	Average
Estimation Sample:	3.56	7.41	5.48
Holdout Sample:	9.01	3.70	6.35

[3] The coefficients of equation 1 and 2 presented in Theodossiou (1989) correspond to standard logistic distribution. In this study, these coefficients are scaled in such a way as to correspond to the logistic distribution function given by $F = 1/[1 + \exp(-Z)]$.

Optimal Cut-off point: 0.25 Efron's R-square: 0.770

The above results do not show any significant difference regarding the performance of the model on the estimation and holdout samples.

To test the merits of the Grammatikos and Gloubos (1988) model, Theodossiou (1991) used his own sample and the five variable sets identified in their study and re-estimated a logit model. This was deemed necessary since use of the Grammatikos and Gloubos estimates to predict firms at risk from Theodossiou's sample would have created a bias in favor of the Theodossiou (1991) model. The estimated results, and the classification accuracy of the model were as follows:

$$\begin{array}{llll} Z = -16.89 - 6.528\, NWC/TA & + 1.680\, CA/CL & - 6.372\, GP/TA\ + & (2) \\ T\text{-value} \qquad\quad -2.47 & 1.56 & -1.60 & \\ \quad +\ 18.56\, TD/TA - 1.418\, GP/CL & & & \\ \qquad\ 5.59 \qquad\qquad -0.78 & & & \end{array}$$

Error Rate:	Healthy Firms	Failed Firms	Average
Estimation Sample:	6.47	9.26	7.86
Holdout Sample:	12.61	11.11	11.86

Optimal Cut-off Point: 0.25 Efron's R-square: 0.664

The Gloubos and Grammatikos profile performed as well as that of Theodossiou (1991) on the estimation sample (years 1980-83). However, its error rates on the holdout sample (year 1984) were higher. In addition, the *CA/CL*. *GP/TA* and *GP/CL* coefficient were statistically insignificant, and the *CA/CL* coefficient had the wrong sign. The fact that the Gloubos and Grammatikos models did not perform well on the holdout sample implies that their models were not robust over time. In light of the above results, this study will only be concerned with the robustness of Theodossiou (1991) model.

3. *Robustness of the Model over Time*

For the successful implementation of a model, its robustness over time is a critical issue. In this section, Theodossiou's (1991) profile of variables and sample are used to further assess the model's stability over the course of the sampling period (years 1980-84)[4]. Table 1 provides the number of manufacturing firms both failed and healthy between 1980 and 1984.

[4] I would like to thank the author for kindly providing the data.

TABLE 1
NUMBER OF FAILED AND HEALTHY MANUFACTURING FIRMS IN THE SAMPLE

Year	Failed	Healthy
1980	9	61
1981	13	73
1982	15	74
1983	17	101
1984	27	111
Total	81	420

Stability of the Model's Coefficients Over Time. – Testing the stability of the coefficients of the logit model over time is a complicated procedure because of the familiar incidental parameter problem (Neyman and Scott, 1948, and Hsiao, 1986, 159-164). To avoid this problem we use a "two stage" logit estimation procedure. In stage one we use the data for the years 1980-84 and the method of maximum likelihood to estimate an "aggregate" logit model $Z_{i,t} = X_{i,t}b$, for $i = 1, ..., N$, and $t = 1980, ..., 1984$, where $X_{i,t}$ is a $1 \times k$ vector including the value of one for the intercept and the explanatory variables for firm i at time t, and b is a $k \times 1$ vector including the aggregate parameter estimates for logit. The aggregate estimates for logit are as follows:

$$Z_{it} = -13.39 - 3.759\, NWC/TA - 13.29\, NI/TA - 7.278\, RE/TA + \quad (3)$$

T-value −2.83 −3.26 −2.68

$$+\, 12.868\, TD/TA + 3.297\, LTD/TA$$

4.79 2.25

Mean square error: 0.03534 Efron's R-square: 0.742

Number of failed firms: 81, and number of healthy firms: 420

All coefficients have the expected signs, and are statistically significant at the five percent level. Efron's R-square is 0.742 indicating a good fit of the data.

Under the assumption that the model is stable over time, logit's yearly deviations from the aggregate parameter vector b should be statistically insignificant, i.e., the model

$$Z^*_{i,t} = X_{i,t}b + \Sigma d_t X_{i,t}\gamma_t$$

where d_t takes the value of one for time t and the value of zero otherwise, for $t = 1980, ..., 1984$, and γ_t's are yearly deviations from b, should reduce to:

$$Z^*_{i,t} = Z_{i,t} = X_{i,t}b$$

After estimating the aggregate coefficients b, the index $Z_{i,t}$ is then computed for each firm and year. Under the assumption that the model is not stable over time a firm's probability of failure at time t is calculated using $F(Z_{i,t} + \Sigma d_t X_{i,t}\gamma_t)$ for $i = 1, 2, ..., N$, and $t = 1980, ..., 1984$, where $F = 1/[1 + \exp(-Z)]$ is the logistic probability function. In stage 2, the above specification of the probability function is used in the usual maximum likelihood estimation framework in order to estimate γ_t and their asymptotic t-values for $t = 1980, ..., 1984$. This estimation procedure is essentially a two stage maximum likelihood estimation of logit. It is based on the analysis-of-covariance test allowing the true model to depend on time as well as to take into account changes in the means and correlations of the model's explanatory variables over the sampling period. Table 2 presents the results which show that the yearly deviations of the model's coefficients are statistically insignificant at the five percent level. Thus the hypothesis of the coefficients' stability can not be rejected.

Predictive Ability of the Model Over Time. – To further assess the robustness of the model over time we use the following sequential procedure. Based on data up to time t, the model was used to classify the estimation sample as well as to predict firms in year $t+1$. The model was then updated each year. In our case, this procedure resulted in five years of classifications and four years of predictions. Table 3 presents the models by updating the estimation sample each year. These models are referred to by the years of data used in the estimation, e.g., the model based on 1980-82 data is called the 1980-82 model.

The error rates of the models in the groups of failed and healthy firms were computed as follows: first, the model was used to calculate a firm's probability of failure; second, each firm was reclassified in its original group by comparing its calculated probability of failure to a cut-off point (probability); third, if a failed (healthy) firm had a lower (greater) probability of failure than the cut-off point it was misclassified by the model; finally, the error rates in each group were computed by dividing the number of misclas-

TABLE 2
TEST OF THE STABILITY OF THE MODEL'S COEFFICIENTS OVER TIME

	Model's Coefficients and Their Time Variations	T-values
Intercept	*−13.385*	*−5.70*
d80 * Intercept	−15.242	−1.11 **
d81 * Intercept	−26.823	−1.40 **
d82 * Intercept	−10.331	−0.58 **
d83 * Intercept	3.972	0.66 **
d84 * Intercept	−1.085	−0.24 **
NWC/TA	*−3.759*	*−2.83*
d80 * *NWC/TA*	−11.028	−1.24 **
d81 * *NWC/TA*	5.881	1.55 **
d82 * *NWC/TA*	−0.339	−0.05 **
d83 * *NWC/TA*	−3.739	−1.17 **
d84 * *NWC/TA*	2.309	1.04 **
NI/TA	*−13.291*	*−3.26*
d80 * *NI/TA*	29.627	1.27 **
d81 * *NI/TA*	−3.290	−0.32 **
d82 * *NI/TA*	−109.19	−1.58 **
d83 * *NI/TA*	−2.950	−0.19 **
d84 * *NI/TA*	−9.496	−1.10 **
RE/TA	*−7.278*	*−2.68*
d80 * *RE/TA*	−20.976	−1.09 **
d81 * *RE/TA*	−2.319	−0.17 **
d82 * *RE/TA*	15.323	−0.83 **
d83 * *RE/TA*	−10.918	−1.01 **
d84 * *RE/TA*	2.336	0.48 **
TD/TA	*12.868*	*4.79*
d80 * *TD/TA*	16.199	1.11 **
d81 * *TD/TA*	29.696	1.40 **
d82 * *TD/TA*	12.969	0.66 **
d83 * *TD/TA*	−4.815	−0.67 **
d84 * *TD/TA*	0.313	0.06 **
LTD/TA	*3.297*	*2.25*
d80 * *LTD/TA*	7.906	0.83 **
d81 * *LTD/TA*	3.711	0.64 **
d82 * *LTD/TA*	−17.663	−1.50 **
d83 * *LTD/TA*	0.599	0.16 **
d84 * *LTD/TA*	−0.187	−0.07 **

NOTES: ** Statistically insignificant at five percent.
$d_t = 1$ for year t and $d_t = 0$ otherwise, for $t = 1980, 1981, 1982, 1983,$ and 1984.
Number of failed firms: 81 Number of healthy firms: 420

Table 3

ESTIMATES OF UPDATED LOGIT MODELS

Data Period	1980	1980-81	1980-82	1980-83	1980-84
Intercept	−28.625 −2.08	−22.073 −3.68	−16.279 −4.07	−14.142 −4.60	−13.385 −5.70
NWC/TA	−14.760 −1.66 **	−2.5362 −1.00 **	−3.9977 −1.88 **	−5.0327 −2.89	−3.7590 −2.83
NI/TA	16.266 0.70 **	−7.9143 −1.19 **	−9.6232 −1.75 **	−9.5043 −1.98	−13.291 −3.26
RE/TA	−28.192 −1.47 **	−10.792 −1.97	−7.2891 −1.77 **	−9.4384 −2.61	−7.2781 −2.68
TD/TA	29.066 2.00	22.757 3.42	16.545 3.66	13.959 3.96	12.868 4.79
LTD/TA	11.215 1.18 **	4.8774 1.32 **	3.9028 1.45 **	4.0015 1.99	3.2969 2.25
MSE	0.0281	0.0318	0.0309	0.0296	0.0353
Efron's R^2	0.771	0.748	0.765	0.770	0.742
Number of Healthy Firms	61	134	208	309	420
Number of Failed Firms	9	22	37	54	81

Note: The numbers under the coefficients are the *t*-values. All coefficients are significant at 5 percent unless otherwise noted.
** Statistically insignificant at five percent.

sified firms by the total number of firms in the group. The error rates in the failed and healthy groups are known as type I and II errors.

Table 4 presents the classification results of the 1980-81, 1980-82, 1980-83, and 1980-84 logit models on the estimation sample using cut-off points ranging between 0.05 and 0.95. Note that all four updates of the model produce error rates which are less than ten percent in both the failed and the healthy groups. As evidenced from the results, the most appealing performances of the models in terms of minimizing the models' average error rates, are obtained with cut-off points in the range of 0.15 to 0.25.

The next step was to test the ability of the models to predict the conditions of firms in the year subsequent to the model estimation. Table 5 presents the results of testing the predictive ability of the 1980, 1980-81,

TABLE 4
CLASSIFICATION ABILITY OF THE MODEL ON THE ESTIMATION SAMPLES

	1980-81 Model on 1980-81 Data		1980-82 Model on 1980-82 Data		1980-83 Model on 1980-83 Data		1980-84 Model on 1980-84 Data	
Cut-off Point	Type I/ Type II Error	Average Error	Type I/ Type II Error	Average Error	Type I/ Type II Error	Average Error	Type I/ Type II Error	Average Error
	0.0000		0.0270		0.0370		0.0370	
0.05	0.1343	0.0672	0.1490	0.0880	0.1489	0.0930	0.1690	0.1030
	0.0455		0.0541		0.0556		0.0494	
0.10	0.0676	0.0896	0.0751	0.0962	0.0731	0.0906	0.0783	0.1071
	0.0455		0.0541		0.0556		0.0617	
0.15	0.0672	0.0564	0.0673	0.0607	0.0712	0.0634	0.0810	0.0714
	0.0909		0.0541		0.0741		0.0617	
0.20	0.0597	0.0753	0.0529	0.0535	0.0518	0.0630	0.0548	0.0583
	0.1818		0.0811		0.0741		0.0988	
0.25	0.0373	0.1096	0.0433	0.0622	0.0356	0.0549	0.0476	0.0732
	0.1818		0.1081		0.0926		0.1111	
0.30	0.0224	0.1021	0.0385	0.0733	0.0291	0.0609	0.0405	0.0758
	0.1818		0.1081		0.1296		0.1111	
0.35	0.0224	0.1021	0.0337	0.0709	0.0259	0.0778	0.0310	0.0711
	0.1818		0.1351		0.1481		0.1235	
0.40	0.0149	0.0983	0.0337	0.0844	0.0259	0.0870	0.0262	0.0749
	0.1818		0.1351		0.1481		0.1358	
0.45	0.0149	0.0983	0.0288	0.0820	0.0259	0.0870	0.0238	0.0798
	0.1818		0.1622		0.1481		0.1481	
0.50	0.0149	0.0983	0.0192	0.0907	0.0194	0.0838	0.0190	0.0836
	0.1818		0.1892		0.1667		0.1852	
0.55	0.0149	0.0983	0.0144	0.1018	0.0129	0.0898	0.0190	0.1021
	0.1818		0.1892		0.1667		0.1852	
0.60	0.0149	0.0983	0.0096	0.0994	0.0097	0.0882	0.0167	0.1010
	0.2273		0.1892		0.1667		0.2346	
0.65	0.0075	0.1174	0.0048	0.0970	0.0065	0.0866	0.0167	0.1257
	0.2273		0.2162		0.2037		0.2969	
0.70	0.0075	0.1174	0.0048	0.1105	0.0065	0.1051	0.0119	0.1544
	0.2273		0.2703		0.2407		0.2969	
0.75	0.0075	0.1174	0.0048	0.1376	0.0065	0.1236	0.0119	0.1544
	0.2727		0.3243		0.3148		0.3580	
0.80	0.0075	0.1401	0.0048	0.1646	0.0065	0.1607	0.0119	0.1850
	0.3182		0.4054		0.4259		0.4691	
0.85	0.0075	0.1629	0.0048	0.2051	0.0032	0.2146	0.0071	0.2381
	0.3636		0.4324		0.5000		0.5556	
0.90	0.0000	0.1818	0.0048	0.2186	0.0032	0.2516	0.0048	0.2802
	0.5000		0.5946		0.6111		0.6543	
0.95	0.0000	0.2500	0.0000	0.2973	0.0032	0.3072	0.0024	0.3284

Table 5

PREDICTIVE ABILITY OF THE MODEL ON DATA SUBSEQUENT TO THE ESTIMATION

	1980 Model on 1981 Data		1980-81 Model on 1982 Data		1980-82 Model on 1983 Data		1980-83 Model on 1984 Data	
Cut-off Point	Type I/ Type II Error	Average Error	Type I/ Type II Error	Average Error	Type I/ Type II Error	Average Error	Type I/ Type II Error	Average Error
0.05	0.0769 0.0822	0.0796	0.0667 0.0676	0.0671	0.0588 0.1287	0.0938	0.0370 0.2973	0.1672
0.10	0.0769 0.0822	0.0796	0.0667 0.0405	0.0536	0.0558 0.0891	0.0740	0.0370 0.1892	0.1131
0.15	0.0769 0.0685	0.0727	0.0667 0.0405	0.0536	0.0558 0.0792	0.0690	0.0370 0.1532	0.0951
0.20	0.0769 0.0685	0.0727	0.0667 0.0405	0.0536	0.0588 0.0495	0.0542	0.0370 0.1261	0.0816
0.25	0.0769 0.0548	0.0658	0.0667 0.0405	0.0536	0.1176 0.0297	0.0736	0.0370 0.0901	0.0636
0.30	0.0769 0.0411	0.0590	0.0667 0.0270	0.0469	0.1765 0.0099	0.0932	0.0370 0.0901	0.0636
0.35	0.0769 0.0274	0.0522	0.0667 0.0135	0.0401	0.1765 0.0099	0.0932	0.0370 0.0811	0.0591
0.40	0.0769 0.0274	0.0522	0.1333 0.0135	0.0734	0.1765 0.0099	0.0932	0.0370 0.0811	0.0591
0.45	0.0769 0.0274	0.0522	0.1333 0.0000	0.0667	0.1765 0.0099	0.0932	0.0741 0.0541	0.0641
0.50	0.0769 0.0274	0.0522	0.2000 0.0000	0.1000	0.1765 0.0099	0.0932	0.0741 0.0450	0.0596
0.55	0.0769 0.0274	0.0522	0.2000 0.0000	0.1000	0.1765 0.0099	0.0932	0.0741 0.0450	0.0596
0.60	0.0769 0.0137	0.0453	0.2667 0.0000	0.1334	0.1765 0.0099	0.0932	0.1111 0.0360	0.0736
0.65	0.0769 0.0137	0.0453	0.2667 0.0000	0.1334	0.2353 0.0099	0.1226	0.1111 0.0270	0.0691
0.70	0.0769 0.0137	0.0453	0.3333 0.0000	0.1667	0.2353 0.0099	0.1226	0.1111 0.0270	0.0691
0.75	0.0769 0.0137	0.0453	0.4667 0.0000	0.2334	0.2353 0.0099	0.1226	0.1481 0.0270	0.0876
0.80	0.0769 0.0137	0.0453	0.4667 0.0000	0.2334	0.3529 0.0099	0.1814	0.1852 0.0270	0.1061
0.85	0.0769 0.0137	0.0453	0.4667 0.0000	0.2334	0.4118 0.0099	0.2109	0.2222 0.0270	0.1246
0.90	0.0769 0.0137	0.0453	0.5333 0.0000	0.2667	0.5882 0.0000	0.2941	0.2963 0.0180	0.1572
0.95	0.2308 0.0137	0.1223	0.6000 0.0000	0.3000	0.7059 0.0000	0.3530	0.4815 0.0180	0.2498

1980-82, and 1980-83 models on firms from the years 1981, 1982, 1983, and 1984 respectively. The error rates of the first three models fall within the range of cut-off points between 0.15 and 0.25 and appear to be similar to those of the estimation sample. However, the error rates of the 1980-83 model using 1984 firms are higher in the healthy group and slightly lower in the failed group. We believe that this "anomaly" is sample specific and it should not raise any serious concern regarding the model's forecasting ability. This belief arises from the fact that: (a) the model's 1984 deviations from those of equation (3) are statistically insignificant (Table 2); (b) the updates of the model produce reasonable results on the estimation samples; (c) the performances of the first three updates of the model on firms subsequent to the estimation do not show any irregularities.

4. *Implementation of the Model*

For the evaluation of Greek manufacturing firms the following procedure is proposed:

(a) Use equation (3) and data from the financial statements to calculate a firm's Z-score.

(b) Calculate the probability of failure using the logistic probability function

$$\text{Prob} = 1/[1 + \exp(-Z)].$$

(c) Compare the firm's probability of failure to the cut-off point of 0.20. If the firm's probability of failure is greater than 0.20, the firm is classified as potentially failing, otherwise the firm is classified as healthy.

To further illustrate the implementation of the model, consider the following example:

Let the following data represent a hypothetical firm: $NWC/TA = 0.05$, $NI/TA = 0.02$, $RE/TA = -0.20$, $TD/TA = 0.90$, and $LTD/TA = 0.50$. From equation (3) we find that the firm's Z-score is $Z = 0.8415$ and the probability of failure is $\text{Prob} = 1/[1 + \exp(-0.8415)] = 0.6988$. Since $\text{Prob} > 0.20$ this firm is classified as potentially failing.

5. *Concluding Remarks*

The primary objective of this paper was to assess the robustness over time of a Greek business failure prediction model by utilizing two new tests. The results indicated that the model was robust. Specifically, the time deviations of the model's coefficients were statistically insignificant. In addition, sequential evaluation of the model's predictive ability on sample of firms from years subsequent to estimation of the model yielded relatively constant error rates over time in both the failed and healthy groups. These results provide additional evidence in favor of the use of business failure prediction models for measuring the risk of insolvency of Greek businesses.

Also, this paper presented a two stage estimation procedure for testing the stability of a business failure prediction model's coefficients over time. This procedure provides a simple solution to the "incidental parameter problem" associated with probabilistic models such as logit, probit, or linear probability model.

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ROBUSTEZZA DEI MODELLI DI PREVISIONE DEI FALLIMENTI IN GRECIA

Lo scopo di questo articolo è di valutare la robustezza nel tempo dei modelli di previsione dei fallimenti in Grecia. Vengono introdotti due nuovi test. Il primo si basa su una procedura di stima logit a due stadi per verificare la stabilità dei coefficienti dei modelli di previsione dei fallimenti nel tempo. Il secondo è una procedura sequenziale dell'errore di previsione per valutare la capacità di previsione dei modelli nel tempo. Questi test vengono applicati ai modelli di previsione dei fallimenti sviluppati da Theodossiou (1991). I risultati indicano che questi modelli sono robusti.

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HEALTH CARE EFFICIENCY MEASUREMENT: AN APPLICATION OF DATA ENVELOPMENT ANALYSIS

by
Sam Mirmirani * and Hsi-Cheng Li **

Introduction

Health care has become the largest and fastest growing industry. In the United States, it currently consumes roughly 14 percent of the GNP and increases faster than the national inflation rate. There has recently been a slowdown in the growth of medical costs; yet in 1992, health care costs rose 10.3 percent while the average inflation in the United States was approximately 3 percent. Compared to other industrialized countries, the United States has the highest per-capita health care expenditure. However, a survey of 10 nations shows that Americans are the least satisfied with their health care system (Wagner, 1990). Over the years, numerous attempts have been made both at the state and the federal level, to impose cost control. These efforts ranged from promoting competition to regulating rates. Despite these reforms, the health care industry still experiences serious unresolved problems in costs containment. It is therefore not surprising that the main thrust of the current debate on health care reform in the United States centers on containing costs and improving access without sacrificing quality (Noble, 1992; Davis, 1991; and Enthoven, 1991).

Most recent studies attribute the high costs of health care in the United States to inefficiencies that plague the industry. These problems range from shortages of hospital beds from the mid-1960's to the mid-1980's (Mirmirani and Ott, 1990) to nursing shortages (Mirmirani and Spivack, 1992) and physician surpluses in the 1980's (Kennedy et al., 1987; Wing and Rey-

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nolds, 1988; McDonald and Wilke, 1987). The industry has now reached a critical stage where structural changes in composition and operation are essential for survival (Mirmirani and Spivack, 1993). Thus, one of the most crucial decisions confronting the federal government is the complete overhaul of the health care system.

Numerous efforts have been made to measure the efficiency of health care providers (Banker et al., 1986; Fizel and Nunnikhoven, 1993; Pina and Torres, 1992; Sherman, 1984). This paper reviews the concept of efficient frontier and demonstrates the application of Data Envelopment Analysis (DEA) to measure the efficient frontiers of statewide health care systems in New England.

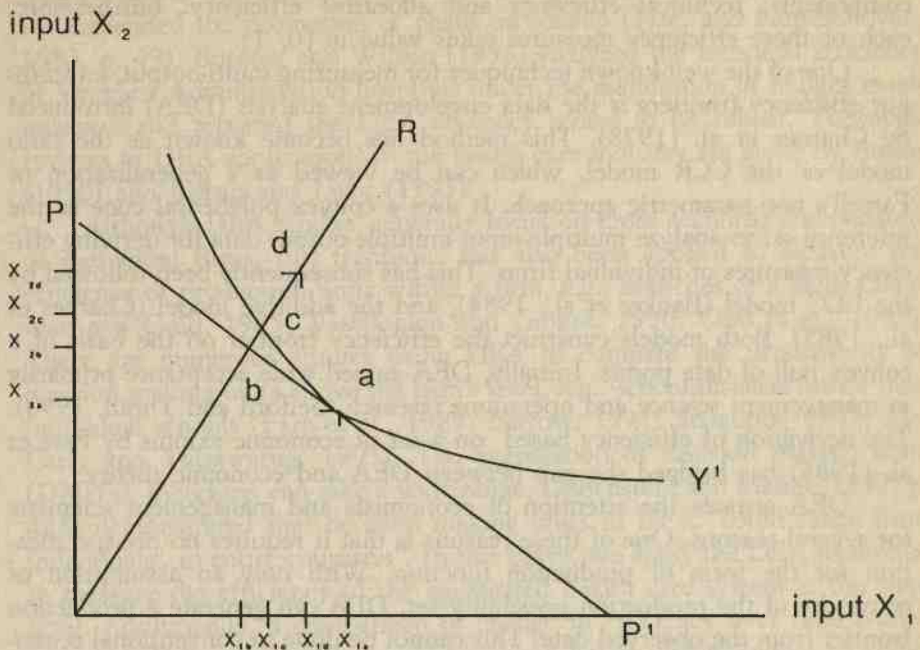
The structure of this paper is as follows. First, a review and clarification of the concept of efficiency are provided. Then, the DEA technique is explained and used to measure the efficiencies of statewide health care systems in New England. At the end, some conclusions are drawn.

Literature Space Review

In traditional microeconomic studies, the parametric approach has frequently been adopted for the estimation of a production function. Farrell (1957) deviated from this convention by introducing a non-parametric approach to establish the piecewise-linear single-output production frontier for an industry. The efficiency of a firm was measured by comparing its efficiency level with the efficiency frontier. Farrell's approach was non-stochastic in nature. Subsequently, Johansen (1972) introduced the concept of a stochastic efficiency frontier.

According to the seminal paper by Farrell, there are two efficiency concepts. Technical efficiency refers to the production of maximum output by using a given combination of inputs, while price or allocative efficiency is defined as the cost-minimizing input mix for producing a specific amount of output at given input prices. Lovell (1993) used the conventional isoquant and isocost concepts to provide a graphical illustration of the differences between cost, technical and allocative efficiency, as shown in Figure. 1. Let X_1 and X_2 represent the quantities of two inputs. YY' is an isoquant curve, while PP' is an isocost curve. The cost efficiency occurs only at the point of tangency between the isoquant and the isocost. That is, the cost efficiency is reached when the ratio between marginal products is identical to the ratio between input prices. This is illustrated by point "a", which guarantees the minimization of cost. The corresponding input mix is X_{1a} and X_{2a}.

FIGURE 1. Technical and Allocative Efficiency in the Production Process.



Consider a technology which is reflected by the OR expansion path. Assume points "c" and "d" reflect the same level of output. A producer who occupies point d requires, say, a combination of X_{1d} and X_{2d} to produce this output. The efficient producer, however, needs only X_{1c} and X_{2c}, which are a fraction (λ) of X_{1d} and X_{2d}. Point d is therefore viewed as technically inefficient. The Farrell measure of technical efficiency of point d is given by

$$\lambda = \{X_{1c}, X_{2c}\}/\{X_{1d}, X_{2d}\} = \lambda\{X_{1d}, X_{2d}\}/\{X_{1d}, X_{2d}\}$$

Although point c is technically efficient, it is not allocatively efficient because it does not lie on the isocost curve. Using the OR technology, the input mix X_{1b}, and X_{2b} of point b is only a fraction (β) of $\{X_{1c}, X_{2c}\}$, the input mix of point c. The Farrel measure of allocative efficiency of point c is

$$\beta = \{X_{1b}, X_{2b}\}/\{X_{1c}, X_{2c}\} = \beta\{X_{1c}, X_{2c}\}/\{X_{1c}, X_{2c}\}$$

The measure of cost efficiency of point d is defined as

$$\gamma = \{X_{1b}, X_{2b}\}/\{X_{1d}, X_{2d}\} = \gamma\{X_{1d}, X_{2d}\}/\{X_{1d}, X_{2d}\}$$

It then becomes obvious that the measure of cost efficiency is made of two components: technical efficiency and allocative efficiency. Furthermore, each of these efficiency measures takes value in [0, 1].

One of the well-known techniques for measuring multi-output, multi-input efficiency frontiers is the data envelopment analysis (DEA) introduced by Charnes et al. (1978). This method has become known as the ratio model or the CCR model, which can be viewed as a generalization of Farrell's non-parametric approach. It uses a convex polyhedral cone as the reference set to analyze multiple-input-multiple-output data for deriving efficiency measures of individual firms. This has subsequently been followed by the BCC model (Banker et al., 1984), and the additive model (Charnes et al., 1985). Both models construct the efficiency frontier on the basis of a convex hull of data points. Initially, DEA gained wide acceptance primarily in management science and operations research (Seiford and Thrall, 1990). The derivation of efficiency based on a set of economic axioms by Fare et al. (1985) has bridged the gap between DEA and economic theory.

DEA attracts the attention of economists and management scientists for several reasons. One of these reasons is that it requires no pre-specification for the form of production function. With only an assumption of convexity of the production possibility set, DEA can generate a production frontier from the observed data. This cannot be done in conventional econometric analysis. A second advantage is that it allows a researcher to identify a production frontier by considering multiple outputs simultaneously. The competing stochastic frontier methodology, on the other hand, allows for the investigation of only one output at a time. Finally, the resulting efficiency scores of some DEA models are independent of input and output units, and therefore make the comparison across decision making units (DMU's) more meaningful.

DEA has recently been adopted as a useful tool for examining the efficiency of the health care industry. In a study of hospital efficiency, Sherman (1984) found the DEA technique superior to ratio and regression analyses. Banker et al. (1986) provided a comparison of DEA and translog production function in their analysis of hospital production in North Carolina. They concluded that the DEA technique offered "richer" and "more diversed" estimates of hospital behavior than traditional econometric techniques. Banker and Morey (1986) relied upon DEA to investigate the performance of pharmacies. In evaluating the efficiency of nonprofit organizations, Pina and Torres (1992) demonstrated the usefulness of DEA in measuring the efficiency of public health services. Fizel and Nunnikhoven (1993) used DEA to estimate and compare the technical efficiency of for-profit chain with for-profit independent nursing homes in Michigan. They discovered the existence of "significant multiplant economies", and therefore recommended the promotion of chain ownership (Fizel and Nunnikhoven, 1993, p. 49). Burgess and Wilson (1993) analyzed the technical efficiency of Veterans Administration hospitals under the assumption of budget maximization and reported the DEA efficency scores to be robust. Thorough reviews of DEA applications in the health care industry are given by Rosko (1990) and Ozcan and Luke (1993).

Although DEA studies generally focus on cross sectional comparisons of individual firms, this technique has also been applied to measure the efficiency of production units within a firm, e.g., branches of a bank (Sherman and Gold, 1985; Vassiloglou and Giokas, 1990; Oral et al., 1992). There are numerous studies using DEA to compare the productivity of decision making units above the firm's level, e.g., school districts rather than individual schools (Fare et al., 1989; Barrow, 1991; Sengupta, 1992; McCarty and Yaisawarng, 1993). The aggregation of decision making units (DMU's), therefore, can take a wide range. Leibenstein and Maital (1992, p. 428) demonstrated that decision making units in DEA "could range from individuals...to entire countries". In this paper, we apply the DEA technique to measure the efficiency of the aggregated health care system at the state level. Additionally, a comparison of change in efficiency over time is also included. This comparison should provide a better understanding of policy issues that the United States is currently debating for its health care market.

Methodology

The health care system in each of the six New England states is considered a decision making unit (DMU). Let X_{ij} represent inputs, where $j = 1, 2, ..., 6$, representing the six New England states, and $i = 1, 2, 3$ pertaining to the three types of inputs: full-time equivalent (FTE) personnel, number of beds, and non-labor expenses. To eliminate the impact of demographic factors on production efficiency, inputs are measured on a per capita basis. Now, let Y_{rj} denote four types of outputs, where $r = 1, 2, 3$ and 4. These outputs include in-patient days, surgical operations, out-patient days and the number of trainees in the designated state's health care system.

Let the health care system of the state under observation be designated by the subscript 0. Following Banker et al. (1984) and Banker and Morey (1986), we have the objective function as:

$$E_0 = \text{Max} \sum_{r=1}^{4} U_r Y_{r0} - U_0$$

subject to:

$$\sum_{i=1}^{3} V_i X_{i0} = 1$$

$$\sum_{r=1}^{4} U_r Y_{rj} - \sum_{i=1}^{3} V_i X_{ij} - U_0 \geq 0, \qquad j = 1, \ldots, 6$$

$$U_r,\ V_i \geq 0$$

where:

U_r = the shadow price of the r^{th} output, $r = 1, \ldots, 4$
V_i = the shadow price of the i^{th} input, $i = 1, 2, 3$, and
U_0 = indicator of returns to scale.

However, this restriction will be relaxed by switching to the assumption of variable return to scale (VRS).

Farrell (1957) placed emphasis on measuring technical efficiency. The measure of allocative efficiency was not suggested because input prices are often highly volatile. In addition, he pointed out that errors in measuring input prices often lead to errors in measuring allocative efficiency. His view has been shared by many researchers who investigate production frontiers.

Since the subject of our study is the efficiency of state-wide health care system, it seems fair to assume that providers of health services are more interested in adjusting inputs rather than outputs for improving their operational efficiency. The technical efficiency score, measured in terms of input utilization, is defined as

$$IOTA = (VIRTUAL\ OUTPUT + OMEGA)/(VIRTUAL\ INPUT)$$

where omega is the constant term, virtual output ($\Sigma U_r Y_{rj}$) and virtual input ($\Sigma V_i X_{ij}$) are weighted output and input respectively.

The data used in this study is obtained from the annual issues of *Survey of Hospitals*, 1985-1990, published by the American Hospital Association. According to the U.S. Department of Health and Human Services (1991, p. 270), percentage change in medical care price index (MACPI) has been consistently greater than the rate of national inflation measured by CPI since the end of the WWII. To minimize the impacts of inflation on input- and output-mix, we select a period with a stable gap of 3.5 percent between

MCPI and CPI. The information on inputs and outputs pertains only to short-term general, non-government, not-for-profit hospitals in six New England states.

Empirical Results

Efficiency scores of the health care systems for the six New England states for the period 1985-1990 are presented in Table 1. Under the assumption of constant return to scale (CRS), the Commonwealth of Massachusetts (MA), with an efficiency score of *one* consistently maintained the leading position. That is, the health care system of Massachusetts had the best resource utilization in New England. Considering the efficiency ranking for individual years, with 1 for the most efficient state and 6 for the least efficient, it is interesting to note that rankings remained unchanged during the period of investigation. Massachusetts had the most efficient system, and Vermont (VT) the least efficient. In addition, all states (with the exception of Massachusetts, which kept an efficiency score of 1 consistently) showed an annual improvement in its efficiency level, except for 1989.

TABLE 1

EFFICIENCY SCORES, NEW ENGLAND STATES, 1985-1990, CRS MODEL

	1985	1986	1987	1988	1989	1990
	(R) Score	(R) Score	(R) Score	(R) Score	(R) Score	(R) Score
CT	(2) 0.607	(2) 0.617	(2) 0.620	(2) 0.632	(2) 0.542	(2) 0.632
ME	(3) 0.238	(3) 0.240	(3) 0.252	(3) 0.292	(3) 0.210	(3) 0.274
MA	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000
NH	(4) 0.200	(4) 0.203	(4) 0.210	(4) 0.215	(4) 0.207	(4) 0.208
RI	(5) 0.187	(5) 0.179	(5) 0.173	(5) 0.175	(5) 0.148	(5) 0.179
VT	(6) 0.103	(6) 0.102	(6) 0.104	(6) 0.107	(6) 0.099	(6) 0.109

(R): Ranking

Under the assumption of variable returns to scale (VRS) the outcome of efficiency scores is quite different. The results of the VRS model are presented in Table 2.

Our research reveals that three states, Massachusetts, Connecticut and Vermont, achieved an efficiency score of *one* for the entire period. Ranking

TABLE 2

EFFICIENCY SCORES, NEW ENGLAND STATES, 1985-1990, VRS MODEL

	1985	1986	1987	1988	1989	1990
	(R) Score	(R) Score	(R) Score	(R) Score	(R) Score	(R) Score
CT	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000
ME	(2) 0.916	(2) 0.932	(2) 0.941	(3) 0.921	(4) 0.842	(2) 0.988
MA	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000
NH	(1) 1.000	(1) 1.000	(1) 1.000	(2) 0.913	(2) 0.931	(3) 0.958
RI	(3) 0.806	(3) 0.865	(3) 0.885	(4) 0.913	(3) 0.924	(4) 0.921
VT	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000	(1) 1.000

(R): Ranking

was assigned with "*one*" for the most efficient and "*four*" for the least efficient health care system. For 1985 to 1987, the ranking of all states remained unchanged. For 1988 to 1990, New Hampshire (NH) dropped in ranking from *one* in 1987 to *three* in 1990. Rhode Island (RI) alternated between *three* and *four*, while Maine (ME) showed a decline from *two* in 1987 to *four* in 1989 and then returned to *two* in 1990.

In addition to the study of relative efficiency ranking among these states, a comparison of annual changes over time reveals an improvement in efficiency by all states. Table 3 indicates that, with the exception of the Commonwealth of Massachusetts and the state of Rhode Island, the net change in the efficiency score, over the period of 1985-1990 for all New

TABLE 3

ANNUAL CHANGE IN EFFICIENCY SCORES, NEW ENGLAND STATES, 1985-1990, CRS MODEL

	85-86	86-87	87-88	88-89	89-90	TOTAL
CT	+0.010	+0.003	+0.012	-0.090	+0.090	+0.025
ME	+0.002	+0.012	+0.040	-0.082	+0.064	+0.036
MA	0.000	0.000	0.000	0.000	0.000	0.000
NH	+0.003	+0.007	+0.005	-0.008	+0.001	+0.008
RI	-0.008	-0.006	+0.002	-0.027	+0.031	-0.008
VT	-0.001	+0.002	+0.003	-0.008	+0.010	+0.006
TOTAL:	+0.006	+0.018	+0.062	-0.215	+0.196	+0.067

England states has been positive. This is an indication that they have experienced some success in improving their resource utilization. The Commonwealth of Massachusetts maintained no change in its efficiency score, since it held the highest score of *one* for the entire period. For all New England states, a cumulative annual change of +0.067 demonstrates a successful attempt to improve resource utilization for the 1985-1990 period.

The cumulative annual change in the efficiency score of the VRS model for all New England states, as presented in Table 4, conforms to that

TABLE 4
ANNUAL CHANGE IN EFFICIENCY SCORES, NEW ENGLAND STATES, 1985-1990, VRS MODEL

	85-86	86-87	87-88	88-89	89-90	TOTAL
CT	0.000	0.000	0.000	0.000	0.000	0.000
ME	+0.016	+0.009	-0.020	-0.079	+0.146	+0.072
MA	0.000	0.000	0.000	0.000	0.000	0.000
NH	0.000	0.000	-0.039	-0.003	+0.027	-0.015
RI	+0.059	+0.020	+0.028	+0.011	-0.003	+0.115
VT	0.000	0.000	0.000	0.000	0.000	0.000
TOTAL:	+0.075	+0.029	0.031	-0.071	+0.170	+0.172

of the CRS approach. That is, with a cumulative change in the efficiency score of 0.172 for the period, the entire region demonstrated an improvement in its resource utilization. As for the annual changes in individual states, a zero change in this table is once again due to the fact that the state had the highest score, namely *one* for two consecutive years. The cumulative annual changes of these states indicates that New Hampshire failed to improve its resource utilization between 1985 and 1990.

Despite differences in efficiency scores between the two approaches, some common elements are revealed when comparing the results provided in Tables 3 and 4. The health care systems in the New England region, with the exception of 1987-1989, exhibited an improvement in efficiency. This is also true when the entire period is considered. The other common element is the experience of the Commonwealth of Massachusetts. Regardless of the model used, it managed to be the most efficient system in the region. This achievement seems to be the result of deliberate efforts made by Massachusetts policy makers to improve their health care system.

New England made a wide range of regulatory efforts in dealing with efficiency improvements. This is particularly noticeable in the emphasis on control over capital expansion and facility since the mid-1970's via Certificate of Need (CON) regulation. Later, in the early 1980's CON was supplemented with strict rate controls. Beginning in the mid-1980's, emphasis has shifted towards promoting competition via health maintenance organizations (HMO's). In a multi-state analysis of hospital regulations and competition, Pallaritto (1992, p. 36) states that "from 1988 to 1991, Massachusetts' reimbursement system controlled prices but also contained some strong competitive features". The leadership and experience of Massachusetts in health policy-making are attributable to its high achievement in efficiency score over the years.

Conclusion

The United States is at the juncture of national health care reform. The issue of efficiency improvement and its ramifications for controlling health care costs will become increasingly important in future policy deliberations. The development of an efficiency measure acceptable to the health care industry and the general public is an essential element in policy formulation.

This study develops a measure of efficiency by applying the Data Envelopment Analysis (DEA) to the health care industry. Although the technique has been used in many studies, the notion of an efficiency score and its measurement for the health care industry, rather than individual hospitals or nursing homes, as developed in this paper, are new. By examining annual changes in efficiency scores we further find that the efforts of a health care system to improve its efficiency can be objectively measured.

As the United States reforms its nearly one trillion dollar health care industry, it becomes apparent that the main focus of the reform initiatives is to "push competition" while "government mandate" and regulatory presence will also be on the rise (Wartzman and Stout, 1993). There are some lessons to be learned from the Commonwealth of Massachusetts since it has consistently scored the highest in efficiency among six New England states. This state has the longest experience with capital expansion controls in the region. At the same time, its policies of rate regulation and the promotion of competition has forced hospitals to search for better resource utilization.

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MISURAZIONE DELL'EFFICIENZA DELLE CURE SANITARIE: UN'APPLICAZIONE DELL'ANALISI DEA

Mentre negli Stati Uniti è in corso la riforma sanitaria, l'efficienza delle prestazioni mediche è diventata un problema del massimo interesse per i responsabili della politica economica. Oltre a una analisi teorica dell'efficienza delle prestazioni, viene qui usato un modello DEA (Data Envelopment Analysis) con tre input e quattro output per misurare l'efficienza dei sistemi sanitari nel New England. La conclusione è che dal 1985 al 1990 si è avuto un notevole miglioramento dell'efficienza negli stati del New England. Fra i sei stati esaminati, il Massachusetts, con i suoi più rigidi controlli e la più lunga esperienza, ha mantenuto il livello di efficienza più elevato.

MISURAZIONE DELL'EFFICIENZA DELLE UNITÀ SANITARIE: UNA APPLICAZIONE DELL'ANALISI DEA

Negli ultimi tempi [illegible] sanitari quali [illegible] è diventato un problema [illegible] più della politica economica [illegible] sanitari, viene qui usato un modello DEA [illegible] input e output per misurare l'efficienza dei [illegible] England. La conclusione [illegible] mento dell'eff[illegible] [illegible] il livello di efficienza più elevato.

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AN ECONOMETRIC INVESTIGATION OF THE HEALTH SECTOR IN GREECE

by
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Introduction

Health economics deals with the study of the allocation of resources to the various health services. In general, econometric studies on the health sector have derived quantitative results on structural relations, such as demand and production of health services etc. The demand for health services has been studied by many researchers like: Feldstein (1966, 1974), Joseph (1971), Grossman (1972), Hoskins (1982a, 1982b), Lavers (1983), Yfantopoulos (1985), Karatzas (1992), Dritsakis (1992). All the above-mentioned studies investigated the effects of the determinants which influence the demand for health services. These determinants include: investments in health, health-insurance, wages and salaries of workers in the health sector, cost of hospital-bed, patients cost etc.

In this paper, the quantitative effects of the basic determinants of the demand for health are investigated with the use of a system of simultaneous equations. Karatzas (1992) implicitly admits the necessity of a multi-equation approach to the problem by pointing out that "... a simplified single-equation approach is used because of data availability ...". Therefore the simultaneity problem is taken into consideration, in this paper, with the use of a model consisting of several equations.

To estimate the model we use data from 1960-1987. All data have been obtained from the Greek National System of Health and O.E.C.D. publications.

Section 2 presents the theoretical model, and the estimates are given in

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Section 3. Section 4 investigates the forecasting performance of the model and discusses some policy experiments. Finally the main conclusions are summarized in Section 5.

The Theoretical Model

Economic theory and data availability led us to the following structural equations:

Labour Demand Function. – It is assumed that when the salary of workers in the health sector increases the demand for labour declines and when the bed occupancy increases the demand for labour increases.

$$L_t = A\, WR_t^{a1}\, N_t^{a2}$$

where: A, $a_2 > 0$, $a_1 < 0$, are parameters to be estimated, and L_t are workers, WR_t is the salary of every worker in the health sector, N_t is the bed occupancy per day [1]. Parameters a_1 and a_2 are the labour demand elasticities of salary and bed occupancy respectively.

Hospital Beds Demand Function. – It is assumed that when the cost per hospital bed increases the number of beds decreases and when bed occupancy increases the number of beds increases.

$$K_t = B\, BR_t^{\beta 1}\, N_t^{\beta 2}$$

where: B, $\beta_2 > 0$, $\beta_1 < 0$, are parameters to be estimated. K_t is the number of hospital beds, BR_t is the cost of hospital bed (not including labour cost).

Parameters β_1, β_2 are hospital beds demand elasticities of the cost of bed and bed occupancy respectively.

Investment Function. – Among the factors which affect the decisions for investments in the health sector is the existing level of the number of beds, K_{t-2}. In other words, if the number of beds in an economy is high then there is little incentive for new investments. An important factor which influences decisions for investments, is the general economic conditions of the country which may be represented by the gross domestic product. Finally, the existence of costs of adjusting capital to its desired level at any

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[1] The variable bed occupancy shows the time a hospital bed is occupied by a patient.

period implies the addition of a lagged dependent variable to the RHS of the investment equation.

$$I_t = \Gamma\, e^{\nu t}\, K_{t-2}^{\gamma 1}\, GDP_t^{\gamma 2}\, I_{t-1}^{\gamma 3}$$

where: Γ, $\gamma_2 > 0$, $\gamma_3 > 0$, $\gamma_1 < 0$, ν are parameters to be estimated. I_{t-1} is investments in the health sector, and GDP_t is the gross domestic product.

Parameters γ_1, γ_2, γ_3 are the investment elasticities of beds demand in previous year, gross domestic product and past investment respectively.

Health Services Demand Function. – It is assumed that there is a positive relation between demand for health services and gross domestic product, and a negative relation between demand for health services and cost of bed occupancy, *PR*.

$$N_t = \Delta e^{\xi t}\, GDP_t^{\delta 1}\, PR_t^{\delta 2}$$

where: Δ, $\delta_1 > 0$, $\delta_2 < 0$, ξ are parameters to be estimated.

Parameters δ_1, δ_2 are the health services demand elasticities of gross domestic product and bed occupancy respectively.

Identities. – The model is completed with the following identities:

Total Cost: $C_t = WR_t\, L_t + BR_t\, K_t$

Cost per bed occupancy: $PR_t = C_t / N_t$

The Estimated Model

The discussion in the preceding section concentrated on the relationship between each dependent variable and its explanatory variables. The model, however, will be solved simultaneously, since such a procedure accounts for the interactions among the endogenous variables. Moreover, a simultaneous equation technique has the ability of reducing the simultaneous equation bias, a statistical problem which causes the OLS estimates to be both biased and inconsistent.

For the reasons stated above, the 2SLS/AR1 estimation process is utilized. The necessary condition for identification is satisfied for all equations implying that they are all overidentified. The estimated equations along with the diagnostic test statistics are shown in the following tables where:

Labour Demand Function:

$$\ln L_t = -13.3004 - 0.2031 \ln WR_t + 1.5580 \ln N_t +$$
$$(-1.9606) \quad (-1.6206) \quad (1.9021)$$

$$+ 0.9173 \ln L_{t-1} \quad (3.1)$$
$$(11.0765)$$

$$\bar{R}^2 = 0.9813 \qquad DW = 2.5382 \qquad F(3,23) = 456.86$$

Diagnostic tests

Serial Correlation: $X^2(1) = 1.9909$
Functional Form: $X^2(1) = 1.5881$
Normality: $X^2(2) = 1.1502$
Heteroscedasticity: $X^2(1) = 0.0379$

Hospital Beds Demand Function:

$$\ln K_t = -4.8745 - 0.0510 \ln BR_t + 0.7339 \ln N_t +$$
$$(-2.3840) \quad (-2.9245) \quad (2.3675)$$

$$+ 0.5544 \ln K_{t-1} \quad (3.2)$$
$$(2.2870)$$

$$\bar{R}^2 = 0.9056 \qquad DW = 1.7547 \qquad F(3,23) = 84.1482$$

Diagnostic tests

Serial Correlation: $X^2(1) = 0.4288$
Functional Form: $X^2(1) = 3.0520$
Normality: $X^2(2) = 1.4209$
Heteroscedasticity: $X^2(1) = 0.3029$

Investment Function:

$$\ln I_t = -1.8162 - 0.0282\, t - 0.8275 \ln K_{t-2} +$$
$$(-0.4425) \quad (-1.2139) \quad (-2.6201)$$

$$+ 0.4712 \ln GDP_t + 0.8744 \ln I_{t-1} \quad (3.3)$$
$$(1.1255) \quad (6.3654)$$

$$\bar{R}^2 = 0.9930 \qquad DW = 1.5697 \qquad F(4,21) = 884.2883$$

Diagnostic tests

Serial Correlation: $X^2(1) = 1.3692$
Functional Form: $X^2(1) = 0.0504$
Normality: $X^2(2) = 2.6046$
Heteroscedasticity: $X^2(1) = 4.8405$

Health Services Demand Function:

$$\ln N_t = \underset{(0.9819)}{1.5300} - \underset{(-3.8655)}{0.0090951}\, t + \underset{(4.9585)}{0.6076} \ln GDP_t - \underset{(-2.2406)}{0.2504} \ln PR_t \qquad (3.4)$$

$\bar{R}^2 = 0.8817 \qquad DW = 1.3583 \qquad F(3,24) = 68.0999$

Diagnostic tests

Serial Correlation: $X^2(1) = 2.6190$
Functional Form: $X^2(1) = 0.6184$
Normality: $X^2(2) = 0.6617$
Heteroscedasticity: $X^2(1) = 1.0484$.

All the estimators have the right signs. The coefficients of the lagged dependent variables is the RHS of the labour and hospital beds estimated demand equations found to be statistically significant. Therefore, the empirical model shows that there are considerable costs of adjusting labour and hospital beds in the health sector. From the estimators of the short-run elasticities, we conclude that the labour demand is elastic with respect to the bed occupancy and inelastic with respect to the wages. The demand for beds is more inelastic in the cost of beds than in the bed occupancy. Investments are more inelastic in the gross domestic product than in the hospital beds. Finally the demand for health services is more inelastic in the cost of the bed occupancy than in the gross domestic product.

The Simulated Model

We tested the forecasting behaviour of the model by doing a dynamic

simulation. The indices used to evaluate the forecasting performance of the model are:
the correlation coefficient between actual and forecasted variables, *r*
the regression coefficient of actual variables on forecasted variables, *RC*,
the Theil's index, *U*,
the proportion of bias, *UM*,
the proportion of variance, *US*, and
the proportion of covariance *UC*.

As we can see from Table 1, the forecasting performance of the model is quite satisfactory.
Tables 2, 3 and 4 show the dynamic multipliers from the 5% increase in the exogenous variables: salaries, cost of beds and gross domestic product and for five years from the initial increase.

From Tables 2, 3 and 4 we conclude the following:

(1) The multipliers take their highest value, positive or negative in the first period after the shock.

TABLE 1

INDICES OF DYNAMIC SIMULATION

INDICES	VARIABLES		
	(*L*)	(*K*)	(*I*)
r	0.98089	0.90412	0.98447
RC	1.01357	1.00108	1.01970
U	0.00224	0.00041	0.00183
UM	0.06420	0.00603	0.06432
US	0.02537	0.02609	0.04279
UC	0.91044	0.96788	0.89289
INDICES	VARIABLES		
	(*N*)	(*COST*)	(*PR*)
r	0.81155	0.99624	0.99518
RC	0.91603	0.99021	0.99329
U	0.00066	0.00048	0.00053
UM	0.00079	0.01147	0.01721
US	0.00140	0.01635	0.00377
UC	0.99781	0.97218	0.97903

TABLE 2

DYNAMIC MULTIPLIERS OF THE 5% INCREASE IN SALARIES

Variable	1	2	3	4	5	Total
Labour	−1.4559	−1.1391	−0.9113	−0.7400	−0.6034	−4.8497
Beds	−0.2238	−0.0302	0.0471	0.0718	0.0757	−0.0594
Investment	0	0	0.1856	0.1873	0.1247	0.4976
N_t	−0.3049	0.1283	0.0870	0.0622	0.0489	0.0215
C_t	0.9182	−0.3830	−0.2599	−0.1861	−0.1462	−0.0570
PR_t	1.2268	−0.5106	−0.3465	−0.2482	−0.1950	−0.0735

TABLE 3

DYNAMIC MULTIPLIERS OF THE 5% INCREASE IN THE COST OF BEDS

Variable	1	2	3	4	5	Total
Labour	−1.2553	−0.8864	−0.6623	−0.5153	−0.4097	−3.7290
Beds	−0.8407	−0.3408	−0.1175	−0.0214	0.0180	−1.3024
Investment	0	0	0.7008	0.8972	0.8821	2.4801
N_t	−0.8076	0.1724	0.0977	0.0596	0.0407	−0.4372
C_t	2.4570	−0.5144	−0.2920	−0.1783	−0.1218	1.3505
PR_t	3.2912	−0.6857	−0.3894	−0.2378	−0.1624	1.8159

TABLE 4

DYNAMIC MULTIPLIERS OF THE 5% INCREASE IN *GDP*

Variable	1	2	3	4	5	Total
Labour	4.7382	3.4524	2.6372	2.0803	1.6663	14.5744
Beds	2.2046	0.8107	0.2074	−0.0399	−0.1333	3.0495
Investment	2.3256	2.0306	−0.0467	−0.7066	−0.7884	2.8145
N_t	3.0159	−0.5456	−0.3271	−0.2108	−0.1515	1.7809
C_t	2.9877	1.6512	0.9856	0.6336	0.4548	6.7129
PR_t	−0.0274	2.2089	1.3170	0.8462	0.6072	4.9527

(2) In most cases, the multipliers tend smoothly to their equilibrium levels after being unstable in the first or second period.

(3) An increase in wages decreases in the short-run the number of workers, the number of beds and number of bed occupancy. On the other hand, it increases the total cost and the cost per bed occupancy and does not affect investments. However in the long-run an increase in wages has an

opposite effect in all variables, except the investments and the number of bed occupancy.

(4) An increase in the cost of beds induces, in the short-run, the same changes in the variables as in (3) above, although the absolute sizes of the changes differ considerably. In the long-run there is a decrease in the number of workers, beds and bed occupancy, and an increase in investments, total cost and cost per bed occupancy.

(5) Finally, an increase in gross domestic product has a positive effect on all variables.

Conclusions

The basic conclusions of the present research may be summarized as follows:

(1) A policy which increases the salaries of those working in the health sector, not only decreases the demand for workers in health but also reduces the demand for hospital beds.

(2) The same results as above has a policy which increases the cost of hospital beds.

(3) Since health is considered to be a "social good" with inelastic demand, a decrease in the number of workers and beds respectively, in the health sector, does not decrease investments. On the contrary, the supply of health services is intensified through increase in the levels of investment. Therefore, it is considered to be a substitution between labour and capital.

(4) From the standpoint of citizens, an increase in the current cost of health services decreases in the short-run the demand of health services; however very soon the citizens come back to the previous levels of demand irrespectively of the cost of health services.

(5) Finally, an improvement in the economic conditions of the country through an increase in the gross domestic product induces an increase in the demands of all factors in the health sector.

APPENDIX

The reduced-form equations of the model are as follows:

$$L^* = A^* + a_2\Delta^* + a_1WR^* + a_2\delta_2PR^* + a_2\delta_1GDP^* + a_2\xi t$$

$$K^* = B^* + \beta_2\Delta^* + \beta_1BR^* + \beta_2\delta_2PR^* + \beta_2\delta_1GDP^* + \beta_2\xi t$$

$$I^* = \Gamma^* + \gamma_1 K^*_{-2} + \gamma_3 I^*_{-1} + \gamma_2 GDP^* + vt$$

$$N^* = \Delta^* + \delta_2 PR^* + \delta_1 GDP^* + \xi t$$

where X^* means $\ln X$.

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UNA RICERCA ECONOMETRICA SUL SETTORE SANITARIO IN GRECIA

Questo articolo sviluppa un modello macroeconometrico per esaminare il settore sanitario dell'economia greca. Il modello consiste di quattro equazioni di comportamento: domanda di lavoro, domanda di letti d'ospedale, funzione di investimento e domanda di servizi sanitari. L'uso di un sistema di equazioni

ha l'importante vantaggio di tener conto esplicitamente dei problemi di interdipendenza.

Il modello è stato stimato col metodo 2SLS e i dati riguardano il periodo tra il 1960 e il 1987. Infine, il modello stimato viene usato in simulazioni per esperimenti di politica economica.